THE GEOGRAPHICAL INTERPRETATION OF TOPOGRAPHICAL MAPS

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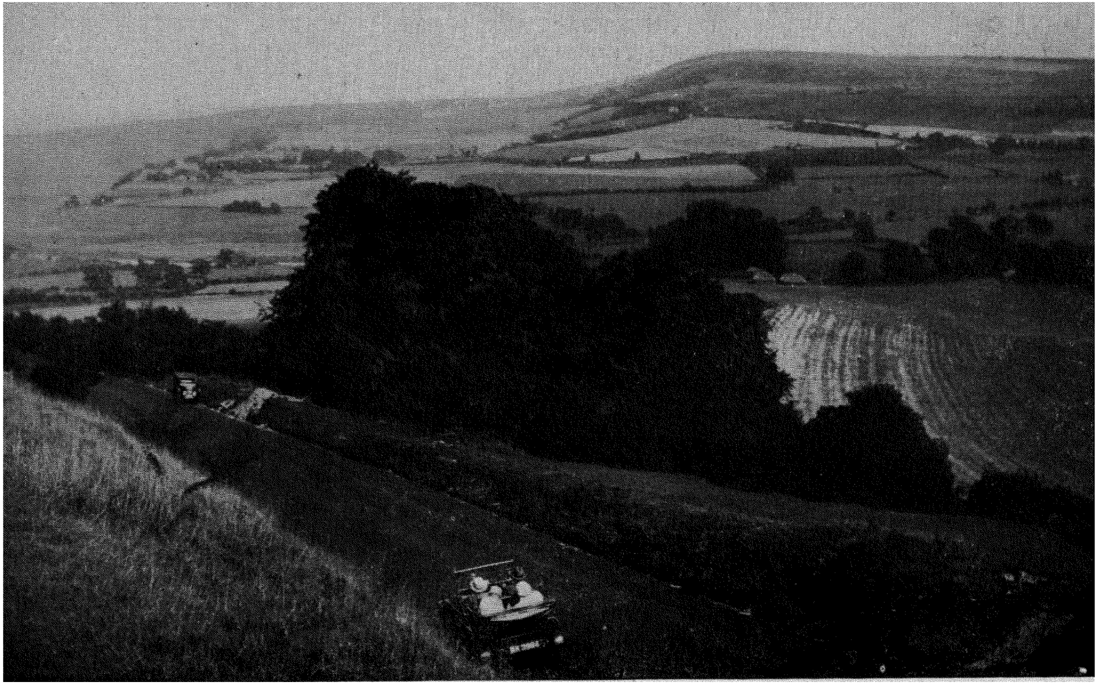

VIEW FROM BURY HILL: THE ARUN GAP (NORTHERN END)

Find the viewpoint on Map III of the supplementary maps.

Fr.

PREFACE

In the following chapters an attempt is made to provide a text-book of map-reading—a subject the nature and scope of which is open to some difference of opinion, judging from the contents of many books written under a similar title. It is hoped that this work may be of use to a large circle of readers, not only to students and teachers in schools and colleges, but also to a wider general public. We live in an age when the use and appreciation of maps, no less than their production, has been increasing by leaps and bounds, and it is becoming more widely realized that from a good topographical map the traveller may acquire a precise and balanced knowledge of a region such as is rarely possible when he depends only on a guide-book.

For the geography student, however, map-reading has a very great significance, and it is with his requirements especially in mind that the text is planned. In the first place, the subject provides invaluable exercises leading to the application or realization of general geographical principles from a study of local examples, and develops the power of logical geographical reasoning. In true map-reading the student should not attempt a *full* geographical account of the region, since he should confine himself to facts that can be traced on the map alone; but in this lies much of the value of the exercise, as it demands an ability to create sound geographical arguments which are none the less valuable because the student formulates them himself. Since the suggestions in many cases call for verification, a simple exercise in map-reading often opens the way for first ventures in research. Furthermore, when the possibilities (and limitations) of map-interpretation are realized a good topographical map becomes a rich source of information, to be used in conjunction with other matter; and therefore

facility in map-reading is an essential part of the geographer's equipment.

The topographical map—from the point of view of map-reading—is of greater geographical value than the cadastral map. The former by reason of its scale allows a study of regional relationships while still presenting considerable detail. For this reason topographical rather than cadastral maps are discussed in the following pages. Nevertheless, many cases exist where a supplementary study of 6-inch or other large-scale maps is advantageous.

There is some difference of opinion as to the value of *geological* maps in *geographical* map-interpretation. By reason of the specialized knowledge required, the reading of a geological map is a subject to itself, and, valuable though this may be to the geographer, it is not strictly speaking his immediate province. Though for many geographical purposes the student must obviously consult the geological map directly, yet it is to be remembered that geological facts of most value to the geographer can frequently be traced on the topographical map from other lines of evidence, as is suggested particularly in Chapter III. Moreover, it often happens that large-scale geological maps are not published or are not available. It is necessary, therefore, that the student should at the outset appreciate possible methods of interpreting geological facts purely from the topographical map, and for this reason he is advised, at least in early exercises in map-reading, to use the geological map as an ultimate source of reference for verifying and amplifying facts of geology which other lines of reasoning may have suggested. Therefore in the following pages direct reference to the record of geological maps is in most cases omitted, the arguments attempting to illustrate methods of geological reasoning from the standpoint of the map-reader only.

Map-reading demands that a student shall not only acquire a particular method of reasoning, but shall also have developed the true geographical outlook, and possess at least a working knowledge of the physical basis and first principles of human geography. This is assumed here. The book is

divided into four sections. In the earlier chapters facts are more especially read *from* the map, while later the possibility of reading facts *into* the map receives more attention. At the same time the geographical matter is classified to provide illustrations representative successively of (1) the more important land-forms and associated physical characteristics; (2) human geography, in relation particularly to types of settlement; (3) the bases of division into natural geographical regions. The latter is especially illustrated in the final chapter, where, too, the possibilities of reading climatic and economic facts are indicated. In no case should the accounts be considered as exhaustive.

The separation of Sections II and III from one another as apparently unrelated subjects (*i.e.*, general physical and human geography) may seem out of harmony with correct geographical method. In theory, it is true, the physical setting should not be considered apart from the human response. But experience with students has convinced me that in the *teaching* of map-reading it is advisable to postpone the correlation until some proficiency is acquired. So great is the wealth of geographical information (both physical and human) which is presented simultaneously by any good topographical map that it is essential for the beginner to concentrate on one aspect of the subject at a time. This has determined the plan of the book.

A comprehensive selection of the larger maps discussed in the text has been issued in a supplementary envelope, in which an attempt has been made to collect a series of map fragments from both British and foreign large-scale maps representing the more important geographical types. This, it is hoped, will in some measure supply a need long felt in schools and colleges in this country. It is surely equally important for children as for older students to study valleys and mountains, town-sites and communications, etc., from maps of things as they really exist rather than from imaginary diagrammatic maps of the type common in many elementary text-books. These (*e.g.*, the regular cone-shaped hill, the road that *invariably* follows the valley, etc.) by their over-generalization and simplification only too frequently

have as little value as the mathematical average, which may seldom occur in fact.

To all those who have helped with suggestions, and in other ways, acknowledgment has been made wherever possible in the text. My special thanks are due to Professor Rudmose Brown, of this University, for valuable suggestions and helpful criticism, to Dr H. R. Mill, for permission to incorporate much material from his paper "A Fragment of the Geography of England," published in the *Geographical Journal*, March and April, 1900, and to Sir Alfred Kitson for information relating to the Gold Coast.

A. G.

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NOTE TO THE SECOND EDITION

FOR the present edition small textual corrections and additions have been made in all sections of the book. Chapter VIII has been largely rewritten, and I have added two appendices—the first to supplement the deductions made regarding the site of Carlisle, and the second to suggest briefly new methods of map analysis regarding insolation as a geographical factor.

A. G.

June 1935

NOTE TO THE THIRD EDITION

A NUMBER of further small textual corrections have been made in all sections of the book, mainly to meet the requirements of the revised series of maps. These are now issued in a separate envelope. Wherever possible the maps have been reproduced directly from the original sheets, and are arranged as loose sheets so as to facilitate their use with the text.

A. G.

March 1953

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SECTION I

INTRODUCTION: GENERAL PRINCIPLES OF MAP-READING

CHAPTER I

PRINCIPLES OF MAP-INTERPRETATION

GEOGRAPHICAL study is dependent upon a symbolic representation of facts to a degree unparalleled in other subjects. For whether one considers the small-scale 'world map' or the large-scale 'plan' of a small unit, the map is but a diagram—though perhaps one which is unsurpassed in general utility, and in some respects least appreciated as a means of the indirect expression of a multiplicity of facts.

In its value to the geographer the map compares closely with the relation of the document or record to the historian. The geologist may study hand specimens from some distant locality and the botanist a preserved plant specimen; but a 'sample' of the world-setting of human activities cannot be transported for study into the geographical laboratory. When analysis in the field is not possible, study depends primarily upon the map, the notation of the geographer.

It is obvious that the map may be called upon to serve a variety of purposes and to represent in a number of different ways some general or specialized geographical problem, for it is a medium of expression capable of endless variations. In this book, however, we are concerned with a particular branch of map-study, wherein it is considered how far by map-study alone one may build up an accurate, vivid, and, to a certain extent, complete picture of the geographical setting and the human response which characterizes any region that is represented in some detail cartographically. The subject of map-reading becomes one of

fundamental importance to the geographer when it is remembered how greatly geographical study depends upon this medium of expression, for if the map be but imperfectly understood, and its possibilities be not fully realized, then inevitably the value will be restricted and the application or deduction of facts distorted.

From the whole range of maps—whatever may be the purpose for which they are constructed—of especial value to the geographer is the topographical map. It stands in a class apart, intermediate between the cadastral map, of very large scale, and used primarily for administrative purposes (*e.g.*, the 6-inch and 25-inch-to-the-mile map of Great Britain), and the small-scale atlas map, where only a very much generalized, and therefore highly diagrammatic, representation of relatively few features can be attempted.

Topographical maps, as the name implies, attempt by a carefully selected symbolism to provide material for an accurate, descriptive interpretation of the region represented. The scale of the topographical map has therefore to be sufficiently large to render possible the inclusion of considerable detail; yet at the same time, if the map is to be graphic, too large a scale may mask the regional setting of the unit. The scale of these maps therefore lies in general between 1 : 200,000 and 1 : 25,000 (*i.e.*, roughly between $\frac{1}{3}$ inch and $2\frac{1}{2}$ inches to the mile). This ensures sufficient freedom for quite detailed representation of the natural features of the earth's surface, while at the same time these will be depicted on a sufficiently small scale to demonstrate quite clearly the regional relations of adjacent areas. A comparison of the scales of some standard topographical maps of several countries seems to show that one which approximates to 1 inch to the mile (1 : 63,360) is found most suitable.

Country	*Scales of Standard Topographical Maps*
Great Britain	1 : 63,360
United States	1 : 62,500
France	1 : 80,000 (old) 1 : 50,000 (new)

Switzerland	1 : 50,000 1 : 25,000
Italy	1 : 50,000 1 : 25,000
Sweden	1 : 50,000
Germany	1 : 100,000 1 : 50,000
Norway	1 : 100,000

Since map-reading should be firstly descriptive, secondly analytic, and thirdly deductive, it is with this class of map especially that we are concerned, for from its symbolism it should be possible to visualize topographic features quite accurately. But at the outset it is important to remember that the topographical map is not the tool of the geographer alone; nor is it therefore constructed with his requirements especially in mind. It is almost invariably in the first place a publication related to military and administrative requirements. We may instance in this respect the fact that the Ordnance Survey of Great Britain, created after the 1745 rebellion, arose under pressure of military requirements, and that the first definite work was that carried out by two generals (Watson and Roy), who worked in the Highlands in 1747. Likewise it is inevitable that military interests should be particularly prominent on some foreign topographical maps. For example, in the "Nouvelle Carte de France" (1 : 50,000) there is a careful discrimination between the type of building material employed in bridge-construction (*e.g.*, whether of wood or stone)—obviously a fact of importance in relation to heavy artillery transport, etc. Landmarks such as churches, monuments, cliffs, etc., are also generally marked on the map.

In addition, however, to military and administrative requirements, information of interest to the historian, antiquarian, or tourist is included, and hence it follows that on any one sheet there is bound to be a considerable mass of material irrelevant to geographical reasoning.

What, then, are the essentials of the topographical map, considered strictly from the point of view of geographical interpretation? A comparison of British and foreign

topographical maps will reveal many contrasts in style of production, in the matter included, and in the ease and completeness with which this may be interpreted. The success of the map depends upon three qualities: (1) what is selected to be shown; (2) how the selected material is shown; (3) how far additional matter is added to provide an adequate code or clue, thereby facilitating map-reading.

(1) Considering first what should be shown, the geographer requires the portrayal at least of the general trend and to a certain extent the detailed form of major and minor features of relief, together with the course of rivers and some impressions of the vegetation which clothes the region. To this must be added the distribution of settlement, evidence as to the occupations of man within the region, and the means of intercommunication by road, railway, river, or canal.

(2) In the expression of facts three qualities especially are requisite. The map should be (*a*) accurate, (*b*) legible, (*c*) graphic. The first is determined primarily by the survey. For the two latter the ultimate control is the scale, upon which the success of the map very largely depends; but almost of equal importance is the choice of appropriate symbols and the use of colour (the latter particularly has revolutionized the possibilities of map-production).

In the choice of symbols the question as to how relief shall be shown probably presents the greatest problem. The difficulties and limitations confronting the cartographer and the variety of methods employed to overcome these will be readily appreciated on comparing sheets from British and foreign surveys. But this problem of cartography will not be discussed here.[1] Suffice it to note that the success of the methods employed to show relief has largely determined the choice of map fragments included in the atlas accompanying this volume. Thus examples of Swiss rather than French or Italian Alpine country have been selected because of the finer cartography of the Swiss 1 : 50,000 map as compared with corresponding topographical maps of the

[1] Consult A. R. Hinks, *Maps and Survey*, also Captain H. G. Lyons, "Relief in Cartography," in the *Geographical Journal*, vol. xliii, March and April, 1914.

other two countries. Several maps from the United States Topographical Survey have also been included, because these, which exhibit almost to an unrivalled degree the possibilities and limitations of contouring in the representation of relief, depict land-forms with remarkable clarity.

(3) No matter how graphic and detailed the map may be, it is nine-tenths useless unless marginal information is added for the use of the reader. Every sheet should contain an adequate key, without which the most perfect map symbolism is rendered valueless. Much other necessary information should be provided. The "Popular" 1-inch map of Great Britain, for example, includes on each sheet not only a detailed key and the statement and drawing of the scale, but also the marking of latitude and longitude, compass points (including magnetic variations), the ruling and marginal numbering of a grid (invaluable for the rapid location of points referred to), an index to adjoining sheets of the same series, dates of surveys and revisions, sheet names, etc. We are so familiar with the use to which the sheet margins are put that we are apt to take these inclusions for granted, but acquaintance with some foreign publications shows how surprisingly frequent in other cases are the omissions. Thus sheets of the 1: 80,000 map of France not only include no statement as to the scale of the map, but commit the unpardonable crime of omitting even an abbreviated key; and this map is by no means the single example among standard European productions (compare the Swiss 1: 50,000 and German 1: 100,000 maps).

In one respect, however, the lack of a key on each sheet becomes less disadvantageous, for it obliges the serious student at least to provide himself with a copy of the 'characteristic sheet.' The latter is published separately for all maps, whether or no a part is included as the key on each individual sheet. It thus happens in England that the majority of students never become familiar with the full code of symbols, simply because for general purposes the abbreviated key is sufficient, and therefore the characteristic sheet remains unpurchased. For detailed map-interpretation this is, however, requisite, and should be consulted for every

map, whether British or foreign.[1] The sheet reveals especially the importance of style of print in providing information as to numbers of inhabitants in towns and villages. (For examples of the use of this evidence see later chapters.)

Among the majority of countries Great Britain stands unrivalled in the variety of complete series of topographical maps which are available. Those of particular value may be classified as follows:

(1) 1 : 25,000. A new map of great value to geographers. Relief shown by contours.
(2) 1 : 63,360, "*Popular*" *Edition*. Relief shown by contours (vertical interval, 50 feet). New road classification. The issue is complete for the whole of Great Britain. This map is recognized as the standard 1-inch map of the country.
(3) 1 : 63,360, "*Tourist*" *Edition*. Relief shown by layer colouring. These sheets do not attempt to form a complete or uniform series. They are published for tourist districts; many are available for Scottish areas. Early issues include hachuring.
(4) "*Special District*" *Maps* (1 : 63,360). Produced in coloured or uncoloured editions for selected districts, particularly where these are inconveniently divided by the sheet margins of the normal standard 1-inch map (see particularly the Dorking and Leith Hill sheet).
(5) 1 : 63,360, "*Outline*" *Edition*. Complete series.
(6) 1 : 63,360, "*Popular*": *Fifth* (*Relief*) *Edition*. A 1-inch map of which some but not all sheets have been available. The cartography of this map is very elaborate (see the Plymouth sheet), and the series was never completed.
(7) ½-*inch Map* (1 : 126,720). Relief: type (*a*) hill shaded (complete issue), (*b*) layer coloured (new edition).
(8) ¼-*inch Map* (1 : 253,440). Layer coloured. Too small in scale to be really effective as a topographical map.

(For a useful summary of these types, together with specimens of the maps and an index to the sheets of the series, see *A Description of the Ordnance Survey Small-scale Maps* (eighth edition), published by the Ordnance Survey Office.) In the following chapters all of the above types of maps

[1] The characteristic sheet for the 1-inch "Popular" edition may be obtained from the Ordnance Survey Office, Southampton.

have been consulted, but the maps of parts of Britain in the main are based on the "Popular" edition.

When confronted with an unfamiliar topographical map it is necessary at the outset, then, to estimate how far this map may be relied upon as providing a piece of geographical apparatus. It is a first essential that every student when beginning to grapple with the problems of map-study should have some experience in the correlation of part of a standard topographical map with the region which it represents in the field. In this way can one best hope to acquire the art of 'seeing the solid' from the flat map-surface. Every student should ramble with the map as his guide, preferably in some area where commanding viewpoints may be reached, whence a panorama gives opportunity for the correlation in the view and on the map of distant landmarks and for practice in map orientation. To walk accompanied always by a map of the district (in one's hand rather than one's pocket!) should be an unfailing habit of the geographer. Only in this way can one gain at first hand a real grasp of the meaning and limitations of map symbolism.

But map-reading, the real purpose of our subject, does not in itself involve field observations with the aid of the map. The geographical interpretation of topographical maps consists in the building of a geographical synthesis *from the evidence of the map alone.* Map-reading is not the compiling of a geographical description or a regional survey of the area included within the highly artificial bounds of a single Ordnance Survey sheet. Nor is it map-reading if we simply write down all that we know about any place which happens to be included on the sheet before us. No matter what facts may be known from independent sources about any region or town, that information should be considered irrelevant until evidence of it can be found on the map itself. Some writers, it should be noted, do not restrict the scope of the subject so closely; others, too, permit the use of a geological map in conjunction with the topographical map. But even this should be avoided, for the geographical interpretation of geological maps is a problem apart, differing from the interpretation of topographical

maps. Since map-reading is purely an exercise affording practice in the application of theoretical geographical principles, it seems to be of far greater value as such if the interpretation is restricted so as to rest on the evidence of the topographical map alone; indeed, as will be seen, the amount of geological fact which may be deduced entirely from the topographical map is often of no small extent or mean degree of accuracy.

Let it not be imagined, however, that in map-reading previous knowledge is of no assistance, or should be neglected entirely. The reverse invariably is true, for knowledge previously acquired adds conviction to surmises which the map may only vaguely suggest, while if we know what should be found or what geographical factors are of first importance it is generally far easier to trace geographical influences from the evidence of the map. Indeed, as the student will realize from the following pages, map-reading may sometimes resolve itself into a search for indirect evidence around which an argument may be developed, to prove from map evidence a fact which was previously known. There is great scope in this direction for the ingenious student in the use of what appear to be non-geographical and indirect lines of evidence.

The task of map-interpretation may begin to assume somewhat unwieldy and vague proportions, and the map-reader may well ask how best one should set about the work of unravelling the medley of fact and surmise presented. Obviously the first step is to gain perfect familiarity with the symbolism, with an appreciation of its limitations as a means of expression. There is as much point in attempting to read a map when unconversant with the code of symbols as to read music without knowledge of musical notation or a book when unfamiliar with the alphabet and language.

One may, then, proceed, from map inspection, to carry out two processes.

(1) First, the material presented must be collected and carefully sorted, so that facts immaterial to the geographical argument may be discarded. As we have seen, the topographical map includes much information of purely general

value, and at first it will probably be found that the amount of 'useless' material included on any one topographical sheet is considerable. But with practice this tends to diminish in extent, for the art of map-interpretation in large measure is a matter of weaving into the argument as evidence facts of all kinds and from all sources, even though these may in themselves be of no geographical interest.

To take a common example, we may read from the map and state the simple fact that between certain points there is a road which is unfenced—in itself a relatively useless observation. But when applied indirectly it is of real geographical importance, for, particularly if correlated with other lines of evidence, the lack of fencing suggests that the region which the road traverses is of small economic value, comprising perhaps mountain or upland pasturage or open heath-land. Local place-names may, again, provide invaluable evidence corroborating historical and geological deductions based upon other lines of argument.

Equal in importance to the facts both presented directly and traced from indirect reasoning are those deduced from negative evidence. We are too prone to accept the facts which are obvious or positive; often it is upon the omission of some characteristic that the strongest proof may depend. Thus a sudden absence of farms or of settlement suggests a change in occupation or in soil types. The absence of double-line railways provides as convincing evidence of the purely local transport requirements of the population as does the presence of the network of winding or branched second-class roads which in all probability equally characterize the same region.

(2) Stage two will comprise the classification of the sorted material according as it may be cited in illustration of some aspect of physical or of human geography—or, it may be, of both. In Chapter III, for example, it will be shown upon what basis the rock of a region may be identified as consisting of limestone. The student should notice the way in which the evidence is collected from widely divergent sources, providing an illustration of the use of quite unrelated facts accumulated in support of an argument, to render it thereby

the more convincing. Much material may be utilized a second or third time; mineral wealth, when marked, provides a clue equally valuable in suggesting the type of rock prevalent as in providing a possible explanation of the segregation of the population in that locality.

In this way, therefore, the material which at first seems overwhelming becomes systematized and graded. This is the task of especial importance in map-interpretation, for which mental equipment and much training and practice is essential, for, as Dr Newbigin pointed out,[1] the mental energy expended upon map-interpretation needs to be greater than that required for ear presentations, since at a glance the eye records from the map a number of facts simultaneously, without reference to their importance, whereas the same facts when read from a book are presented one at a time, in considered order of importance.

If from the map alone it is possible to build the complete picture which we have suggested, it may be surmised that map-interpretation can quite adequately replace field-study. Comparing, for example, the task of the trained map-reader and the field-worker, there may at first glance seem advantages in regional study through map-reading. For by this means, without arduous travel and in a short space of time, one may trace inter-relations and factors controlling distributions which would take the field-worker perhaps weeks or months to establish. The map-reader may see instantaneously the combination of factors determining the location of a town in a way that may not be equalled in the field. The rambler must climb to the summits of the ridge overlooking the isolated valley below before he can gain any perception of the country beyond. On the map this information is placed before the reader immediately; and, as will be demonstrated, he can with practice reconstruct in mind from the map alone the range of view seen from any selected position.

But geography is not the science of reading a specialized type of symbol and diagram. Map-study increases rather

[1] Marion I. Newbigin, *Ordnance Survey Maps: their Meaning and Use*, p. 9.

than diminishes the need for travel. Great though the imaginative powers of the map-reader may be, they can never fully create the atmosphere of the environment represented. At most we tend to see a picture, not a reality. To gain even a slight perception of what the map truly portrays the mind must be enriched by contact with, for example, true mountain, plain, or fenland, with rural life and scattered farmstead as opposed to the unending maze of streets within large industrial centres. Without this our mental equipment possesses no standard or scale of associations or of space relations whereon to base impressions of other regions seen only through map-reading.

Therefore the geographical interpretation of topographical maps consists in *applying*, firstly, the art of visualizing the reality from the symbolic representation, and, secondly, the science of establishing causal relations between "place and folk." The logical processes by which this is achieved are of a distinct type, based upon evidence which is more often indirect than direct, and as frequently negative as it is positive, while the whole geographical synthesis, growing from description, analysis, and generalization, depends more largely upon inductive than on deductive reasoning.

Finally, and for the sake of the beginner, it may be worth while to emphasize two points relating to style of expression. In the first place, since the final geographical description of a region is built up around arguments based upon conclusions from the map alone, it is best to formulate suggestions rather than to state facts, except when we have accumulated from a variety of sources so great a wealth of evidence that no doubts can possibly exist. But we must be prepared to leave many surmises offered purely as tentative suggestions. Often the soundest map-reading is that which offers the least definite or assertive statements.

Secondly, the plea cannot be made too often for a *description of the place and not the map*. The mind must ever "read and not spell" the map, and attempt to describe the region and not the pattern of symbols. Therefore it is as incongruous to talk of "rivers flowing from the north-west of the map" or of "heights attaining to 2000 feet in the centre

of the map" as to speak of the top and the bottom when north and south are meant. The latter error is less common in the reading of topographical maps, because these are generally studied lying horizontally, but the former is a habit of expression, and therefore of mind, which is only too prevalent Trivial though it may seem to insist on the description of features as related to the "area" or "region" under discussion rather than as occurring "on the map," so long as the latter phrase persists it seems a proof that at heart he who uses it has established no inner vision of place rather than symbol.

Note. For general theoretical considerations relating to the cartography of topographical maps students should consult standard works on the subject, particularly *Maps and Survey*, by A. R. Hinks.

CHAPTER II

LANDSCAPE STUDIES THROUGH MAP-READING

First Principles of Contouring

It has already been suggested that the first lessons in the appreciation of topographical maps are best learnt in the field. But when this is impracticable a valuable exercise consists in correlating pictures of some outstanding views with the appropriate sections of the topographical map. Indeed, this should follow field-study in any case as an intermediate step in the teaching of map-interpretation.

The photograph with Map I in the envelope represents a view in the Lake District, looking across Ullswater toward the summits of Helvellyn. A ridge rising from the farther lake-margin forms a conspicuous feature in the middle distance. This may be correlated with the ridge AB on the map. It is easy to imagine the trend of the contours actually in the field, around the ridge. The plane of each lies parallel to the surface of the lake, but every contour follows the curve of the hill features, bending outward around the terminal knoll at *a*. The latter rises slightly higher than the main ridge immediately to the right, so that, given a suitable vertical interval between successive contours, a closed circular contour should pass completely round the upper slopes, just as is actually represented on the map at A. Similarly, behind the col marked at C on the map the contours curve in a long protuberance typical of the spur, so that BC on the map compares with *bc* in the view. At *b* in the picture the spur is slightly furrowed by a small gully, where a tiny mountain torrent is probably cutting back into the hillside. This on the map is represented at B, where the stream itself is marked—obviously by a line whose thickness and intensity is out of proportion to the volume of the

diminutive water-course, while the furrowing of the hill-slope is shown by the slight upstream bend in every contour. Thus there are illustrated in this small section four fundamental contour groups (viz., the knoll, pass or col, spur, and gully), whose identification is important in aiding concise description. A valley is always represented on a contour map by a re-entrant in which the contours 'tongue' upstream. In the case of this gully a valley of the most youthful type is represented.

Immediately behind the ridge *acb* the photograph indicates a deep, long, and relatively broad valley, which may be identified on the map as Grisedale, overlooking which at D and *d* respectively in map and photograph lies St Sunday Crag, and, at E and *e*, Birks Hill. Many other forms of upstream re-entrants occupied by rivers or streams may be identified, indicating valleys of varying form and gradient.[1] The student should proceed to identify as many features as possible on map and photograph; particularly clear, for example, may be the comparison of the lake-margin, and the identification of the subcircular flat delta where Red Tarn Beck (Glenridding) enters the lake. Woods, roads, and even individual houses may similarly be identified. The map, however, denotes the occurrence of additional features which, owing to their distant position, cannot be seen in the photograph—such, for instance, as the cliffs and edges which, according to the map, occur along the ridges bordering Helvellyn and below St Sunday Crag (*d, f, g,* in the photograph). The crest of the Helvellyn ridge, with its extension southward and south-eastward (note the orientation of the map), forms a water-parting or divide between the drainage to the Ullswater and Thirlmere basins. It is useful in a preliminary survey to trace the line of the water-parting between major drainage systems, for without exception it will be found to be sinuous rather than straight, especially where the divide has become markedly narrowed. The identification on the map of distant ridges and peaks shown in the photograph is more hazardous, for it may be difficult

[1] The importance of the varying forms of the re-entrant in relation to valley types will be discussed particularly in Chapter IV.

to decide which of several eminences is the particular summit shown. The tests to be applied demand ability to estimate the range of visibility.

INTERVISIBILITY

One disadvantage of contouring as a method of showing relief (and one which is sometimes overlooked) is that theoretically there is always a slight error in the distances

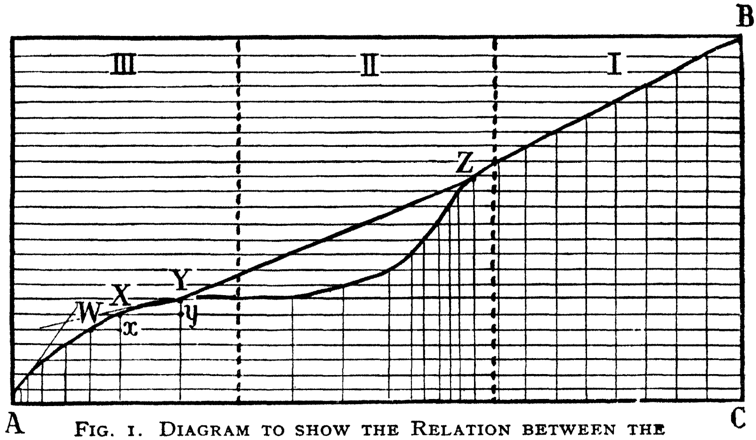


FIG. 1. DIAGRAM TO SHOW THE RELATION BETWEEN THE LENGTH OF THE HORIZONTAL EQUIVALENT AND SURFACE GRADIENTS

between contours on the map as compared with the corresponding true distances on the ground, although the error becomes almost negligible in amount except on steep slopes. For instance, in Fig. 1 the distance between two consecutive contours on the ground is the length WX, but on the map this is represented by Wx; or, similarly, the entire undulating distance AB is represented on the map by the length AC. These distances on the map are obviously too short to represent accurately the lengths on the ground, and are therefore known as the *horizontal equivalents* (generally abbreviated to H.E.). As to how far it is necessary to make allowance for this error we will consider later, but it may be noted now that the error is least for slopes of gentle gradient,

and becomes steadily greater with the decreasing length of the H.E.; this is evident when the lengths WX : Wx are compared with XY : Xy.

The vertical distance between two contours is known as the *vertical interval* (V.I.)—for example, in Fig. 1 xX and yY, or BC in relation to the composite horizontal equivalent AC.

A feature which the diagram (Fig. 1) especially illustrates is the way in which the H.E. varies in length according to the slope, rendering contours closely packed or widely spaced. The profile may be divided into three sections, according as the surface presents an even, concave, or convex slope. Each is typified by a distinctive contour grouping, indicated along the line AC, where the following fundamental rules of contouring are therefore exemplified:

(1) The more closely contours are spaced (given a constant V.I.) the steeper is the gradient which they represent.

(2) Where a number of contours are equidistant (and therefore the H.E.'s are of equal length), there the slope will be of uniform gradient (see section I of the diagram).

(3) A concave slope will be represented by contours becoming first widely spaced and subsequently closely packed at higher altitudes (see section II).

(4) A convex slope, on the other hand, is represented by contours closely packed at lower altitudes and becoming more widely spaced above (see section III).

Merely from an inspection of the contours on the map we should, then, be able to tell much as to the variations in profile. For example, the climb up to St Sunday Crag (Map I) from, say, a point at H will be steeper and more strenuous than that up toward Striding Edge from the same starting-point. The stream line of the Grisedale Beck presents a conspicuously concave profile when traced from its source to Lake Ullswater. Particularly in the upper valley section the contours are very closely spaced, and the slope correspondingly steep. Again, in the valley above Thirlmere one climbs by very steep gradients to an altitude of about 1650 feet, whence, until 2000 feet, the slope is much

more gentle, the whole therefore comprising a hillside of very distinct convex profile. Above 2000 feet the contours again become more closely spaced, to indicate a steeper but more or less unvarying gradient. The climb up to Dollywaggon Pike would be relatively stiff. Many types of hill profiles can be identified in this way.

On Map I the contour V.I. remains constant (at 50 feet) throughout the entire range of relief, but this is not the case with every topographical map, and it is therefore necessary for students to note carefully whether changes occur before making general estimates of changes in the slope. For example, on the "Fully Coloured" edition of the 1-inch map, at an altitude of 1000 feet the V.I. changes from 100 feet to 250 feet. This tends to give a very distorted impression of the relief, even when we are prepared and know that the change occurs, for the increased V.I. naturally leads to a lengthening of the H.E., even though the slope remains unchanged. The dangers of the system are illustrated in Fig. 2, which shows a small section of Grisedale contoured as on the "Fully Coloured" edition. It should be compared closely with the corresponding district in Map I. The changed V.I. gives an appearance of convexity to the slope of each valley-side, whereas the more accurate and unchanging system of contouring in Map I shows that the reverse type—concave rather than convex—is actually present for most of the hillsides. This changed V.I. is one of the greatest faults in the cartography of the "Fully Coloured" 1-inch map.

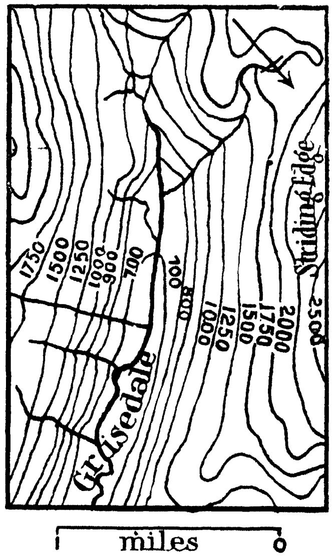


FIG. 2

V.I., 250 feet above 1000 feet.

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

The identification of convex and concave slopes is of importance in determining the range of visibility; for example, in the profile of Fig. 1 it is not possible to view Y from A (or *vice versa*), because of the convexity of the hill profile. On the other hand, Y and Z are visible one from the other. Applying this principle to Map I, we may suggest that A is not visible from the flattened upper slope at 2250 feet.

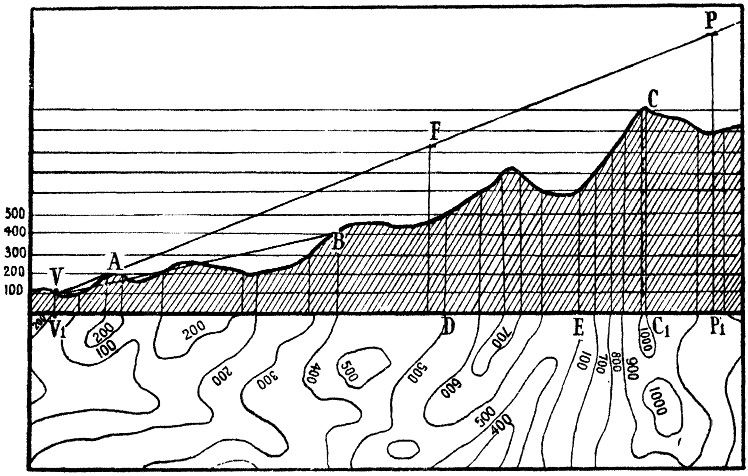


FIG. 3. METHOD OF DETERMINING INTERVISIBILITY

Where slopes are of even gradient positions should be intervisible—at least theoretically; but quite a small under feature, which may scarcely be perceptible from the contouring, or even a house or woodland, may block the range of view. Close inspection, not necessarily of the contouring alone, is needed in these, as, indeed, in all cases. These examples of visibility apply, however, only to very local single hill profiles. When it is desired to know whether distant peaks can be seen contour inspection alone is not sufficient. Even in the case of the view A to K, though we may identify convexity up to 2250 feet, yet it cannot be ascertained without further experiment whether the much higher Helvellyn Peak is or is not visible over the brow of the convex slope.

It is necessary in these cases to plot either a full or a skeleton section along the line of sight. The heavy undulating line in Fig. 3 illustrates a section drawn along an imaginary sight-line from a viewpoint at V toward a distant peak, C. The line VP represents the skyline of sight. If CV or even BV are joined, then the lines cut through the low hill at A. The latter eminence must therefore block the view to both B and C, and this therefore determines the angle which the line VP makes, for it needs to be tangential to the summit of the hill A. From the map (below the profile) it would seem almost certain that from the point V (100 feet high) the point C (1000 feet) could be seen, since there is no higher ridge intervening, and it is doubtful therefore whether from only a casual inspection one would imagine that hill A, not 300 feet in altitude, would block the view to the more distant peak. The diagram shows how the nearer the eminence be to the viewpoint, the lower need be the altitude of the former for it to obstruct the view to more distant heights.

Thus C, though over 1000 feet in altitude, is still well below the line of sight. If we imagine that the land at P rises sufficiently high to cut the sight-line VP at P, then that height will be visible behind the foreground ridge at A. But it should be noticed that not until a height of 1400 feet is attained will visibility in this instance be possible. A peak at F, however (a position much nearer the viewpoint), could be seen from V if only 850 feet in altitude. In first efforts at determining visibility it is advisable always to draw the full section, but later it will be found sufficient to draw only what is known as a skeleton section, which may be constructed either on the map itself or on separate paper.

For this, it is necessary only to erect perpendiculars at appropriate positions along the section line (*i.e.*, line of sight), their height representing to scale the altitude of the summit which they denote. For example, the imaginary peak P in Fig. 3 is shown simply by a vertical. If at F the land rose to 850 feet, then a perpendicular drawn to scale would here meet the sight-line, and therefore obstruct the

view from V. The omission of intervening curves of the section line in this way effects a considerable saving of time.

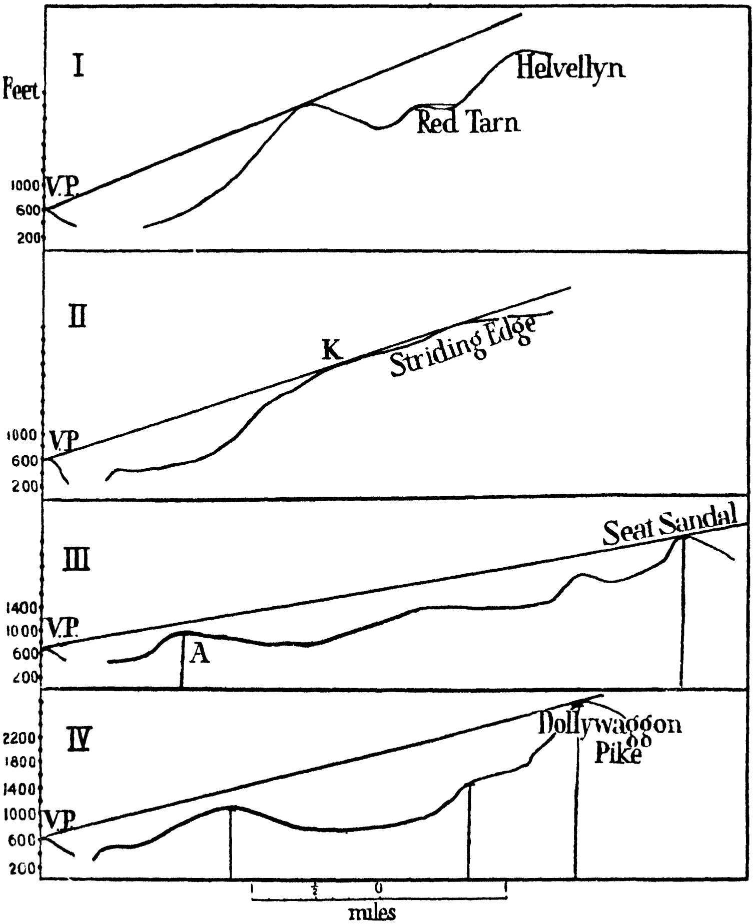


FIG. 4. INTERVISIBILITY TEST SECTIONS FROM O

See Map I in the atlas.

The student may now apply a number of section tests for intervisibility from O (Map I), a few of which are shown in Fig. 4 (as both full sections and skeleton sections in the

case of III and IV). (*N.B.* The actual orientation of these sections only approximately coincides with that of the lines marked on Map I, which are drawn for other purposes.) All four sections radiate from O (a station at a height approximately of 650 feet), and are orientated to (1) Helvellyn, (2) Striding Edge, (3) Seat Sandal, (4) Dollywaggon Pike. They illustrate how far these landmarks are visible from a viewpoint at O.

Section I is of interest in that it shows how Helvellyn, scarcely four miles distant, and attaining to a height of over 3000 feet, is cut out from view by the ridge to the fore. The whole upper valley occupied by Red Tarn is similarly not visible. Section II shows the type of profile where it is inadvisable to use the method of skeleton section drawing. Here again the lower ridge at K just hides the steadily rising ridge crest of Striding Edge. Section III is drawn through the knoll A, which we have identified as forming almost the central feature of the photograph. Away in the distance, as the map shows, the land slopes up to the peak called Seat Sandal, and the question arises as to whether the front knoll is of sufficient altitude to block the view. The section shows that Seat Sandal should be seen, and therefore it is probable that this is the peak in the farthest distance in the view. *l* lies just behind the knoll *a*, and just appears between St Sunday Crag on the one hand and Dollywaggon Pike on the right. It is noticeable in the photograph that Seat Sandal (*l*) drops rather abruptly to the left, and this shape the map corroborates, since it shows closely spaced contours and cliff-shading on this side of the peak. The conspicuous ridge in the photograph, between the two peaks, is presumably that between Dollywaggon and Nethermost Pikes, for we have found that Helvellyn cannot be seen, and, furthermore, section IV, to Dollywaggon Pike, shows how clearly evident this peak should be from O.

Identification of the Viewpoint

It remains to identify the exact viewpoint on the map from which this photograph was taken, and this can be

effected by selecting on different parts of the photograph two or more points which lie immediately in line one above the other, and which can be identified with certainty on the map. Thus a vertical line joins the islet, the corner of the lake, and Gavel Pike (to the left of St Sunday Crag). These points, lying one behind each other in the view, should equally fall in alignment on the map if their identification has been correct. They are joined on the map by the line from X through Gavel Pike and the lake-corner. Similarly, the islet to the right of the view and the margin of the woodland at *b* (in the gully) are in alignment on photograph and map—joined on the latter by a line through Y. When produced, these two lines will meet, and the point of intersection should mark the viewpoint (*i.e.*, in this case O, where OX and OY meet). But before definitely accepting this point as the required position further tests should be made by drawing and producing lines through other pairs of features which have been identified with certainty on both map and photograph. Further, it is clear in the photograph that from the *actual* viewpoint (wherever this may be) certain peaks are visible. It should be tested whether this would also apply from the supposed viewpoint on the map.

In selecting the pairs of points on the photograph it is advisable whenever possible to choose one in the foreground and one quite distant, indicating that a fair distance intervenes on the map, thereby rendering the orientation of the line more accurate. The student should draw in some of these lines—*e.g.*, (1) from the delta, through the col *c*, to the gentle slope below Dollywaggon Pike; (2) from Nethermost Pike to the hamlet where the main road crosses the Glenridding delta. These should focus on to the same viewpoint at O, which, it may be noted, happens to fall on the footpath leading up to Silver Hows—a very likely position for a photographer to use in such a region. Finally, we should draw in radiating lines from O which delimit on the map the district shown in the entire view. The lines I–II and III–IV, bounding the photograph, will represent on the map radii from O, diverging out toward the horizon line. Therefore from O we may draw a line practically through the

mouth of the Goldrill Beck (where it enters the upper end of Lake Ullswater), for this is seen on the extreme margin of the picture. From O a similar bounding line may be drawn just to the right of the islet which represents that shown in the view at the extreme right. With centre O and radius OL (*i.e.*, to include Seat Sandal, the farthest point shown) an arc of a circle may be drawn, completing the 'triangle' of map delimited between these two arms.

A line from O through the knoll to Seat Sandal practically bisects this triangle, just as the line through the same points bisects the photograph, thereby proving that the orientation of map and view is correct—facing to the south-west. This exercise reminds us of a fact often overlooked—that the section of the earth's surface which we see in a picture or in the actual landscape is in reality triangular in shape and extremely foreshortened.

Having found the exact viewpoint and orientation, we may ask ourselves if it is possible from map tests to find out whether we can climb high enough to see some of the summits which are not visible from the footpath, or whether any well-marked peaks will disappear from view with a slight change of position. The two examples in Fig. 5 illustrate the method by which such facts may be deduced. Section I shows the profile to Seat Sandal from O. If a line is drawn from this peak to cut just below the knoll summit of A, and is then produced until it cuts the section line in the vicinity of the old viewpoint, then obviously this line will represent the line of sight from a station where Seat Sandal is just cut out of the view behind the knoll A, and the point of intersection of sight-line and profile represents the position of the viewpoint where such conditions obtain (*i.e.*, $V.P._2$ in section I, Fig. 5). Reading from the vertical scale, this point occurs at an altitude of about 500 feet, and by comparing map and profile it will be found to lie forward, in front of the footpath, near the water's edge. Therefore if we descend from the footpath to the lake-margin Seat Sandal will have passed below the horizon, the skyline now being outlined by the knoll A.

Again, section II shows the profile from O to Helvellyn,

the view to which is obstructed by the fore ridge at B. If from Helvellyn we draw a line which this time just *clears* the summit of peak B, and produce this back to cut the section line, we shall obtain a second viewpoint, from which Helvellyn is now visible. In this case the new viewpoint lies behind the original viewpoint, and therefore it is necessary to continue the profile drawing back behind the point

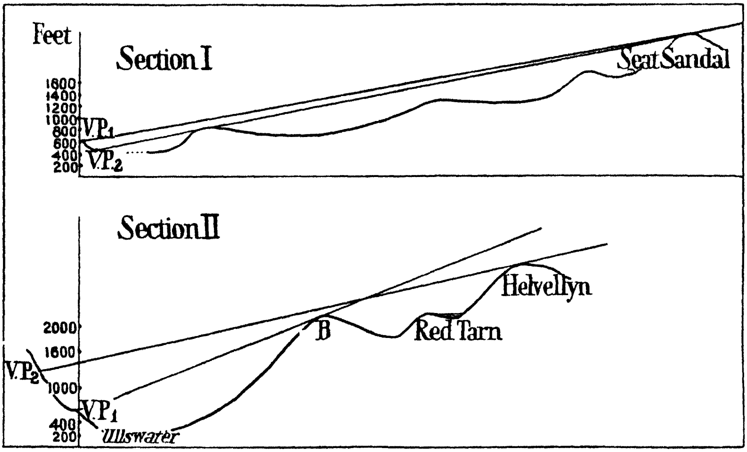


FIG. 5

O, until sufficiently produced for the new sight-line to intersect it. Sometimes this is impossible, for the topography behind the old viewpoint may not rise sufficiently high, in which case one assumes that, at least in the immediate locality, there is no possibility of viewing the hidden peak. In this case, however, the land rises quite abruptly, and the sight-line from Helvellyn cuts the extended profile at an altitude approximately of 1300 feet. This position, on comparing map and section, is seen to lie amid craggy and precipitous slopes, and therefore, judging from the map, if Helvellyn is to be seen it is necessary to perform some mountaineering feats among the cliffs and crags above the footpath, and this is likely to entail sufficient preoccupation to interfere considerably with our appreciation of the view

behind! It is more likely, therefore, that we shall choose a less precarious route and viewpoint for a first glimpse of this well-known summit, and the student may amuse himself endeavouring to find out where this may lie, plotting on the map the suggested positions and line of approach.

The Drawing of Pictures from the Map

The second view (of Map II) purports to be a profile sketch of the probable view from a boat stationed at Y (Map II), looking landward toward Llandudno. For the construction of these view sketches a little more imaginative power may be necessary, but they are based primarily upon estimates of intervisibility. The view in the drawing is bounded on the map by the lines 1 and 16, and the horizon line is assumed to be just over ten miles distant from the viewpoint. A small section of the arc is seen at X, and this should be continued over the map margins to cut the bounding radii (produced) if it is desired to show the entire area included in the view. The hill outlines have been obtained from the erection of fairly closely spaced verticals, whose varying height is obtained by the projection of the line of sight to intersect a perpendicular erected at the horizon for each of a great many closely spaced sections, radiating from the viewpoint at Y.[1] Skeleton sections have therefore been drawn along each of lines 1–16, with the addition of some further intermediate profiles where necessary. Only four of these—drawn as full sections—are shown here, in Fig. 6, to correspond to lines 1, 4, 5, and 6 on Map II. The process of view construction may at first seem somewhat involved, but if the student follows step by step through the following explanation the principle will be quite readily understood.

In section I (Fig. 6) a line of sight is drawn to *a* (Great Orme's Head), and then continued for the full length of the section to the horizon (although no land area is present). The length AB along the perpendicular at the horizon represents the *apparent* height of the promontory as seen from Y.

[1] This is based on the simplified examples given by J. Fairgrieve in *Geography in School*, p. 164.

This distance is transferred to the view under construction, and set up as a vertical at (1), AB. To obtain the apparent height of the cliffs (which are marked clearly on the map, and therefore, it seems reasonable to suggest, will be evident

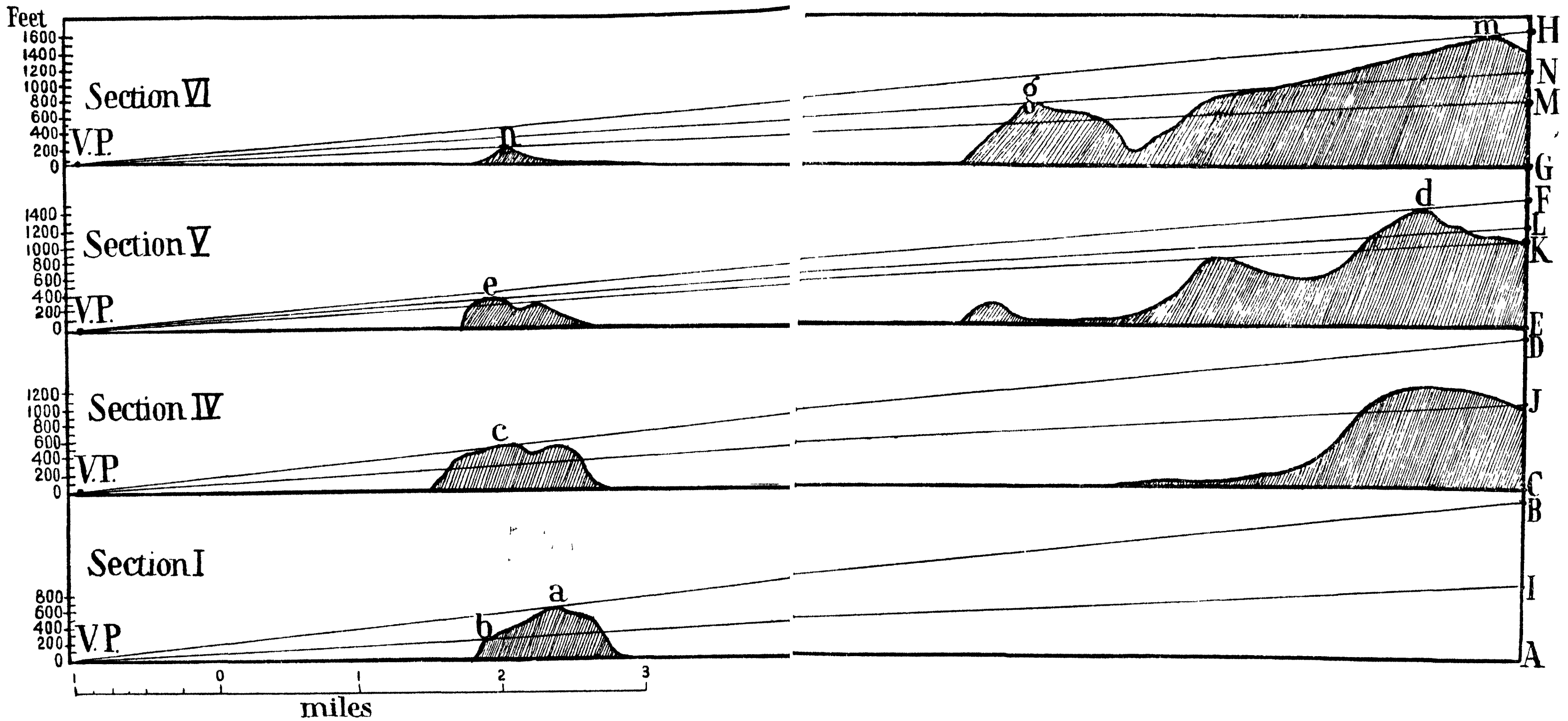


Fig. 6. Construction preparatory to the Sketching of Views from Maps

from the sea), V.P. (Fig. 6) is joined to *b*, and thence projected again to the horizon line. The distance AI is then set up at (1) in the view. In this way the apparent heights *at the horizon* are found for all landmarks along as many sections as possible, and these distances are transferred to the base line of the view.[1]

[1] The curvature of the earth (roughly 6 feet in 3 miles) is so slight that its effect may be ignored in this exercise.

It yet remains to note how the distances apart of perpendiculars along the base line of the view are determined. These distances are obtained by measuring the length along the arc of the horizon line on the map between successive radii. For example, the distances between (8) and (7), (7) and (6), etc., on the arc passing through X (Map II) are transferred to the base line of the picture as the distances (8)–(7), (7)–(6), etc., and at each of these points the verticals (whose length has been calculated from the respective sections drawn elsewhere) are set up. As already noted, only a small section of the entire arc necessary for the construction of the view has been included on the map here, but no

landmarks visible from Y between the radii 1 and 16 have been excluded from the map as a result of this omission. When a sufficient number of verticals has been erected, then a curve may be drawn joining their summits, and it is thus that the profiles of the drawing from Map II have been obtained.

Sections IV, V, and VI (Fig. 6) show how the detail of fore ridges and under features may be added. In section IV, for example, the promontory blocks the view to the escarpment on the farther side of the Conway estuary, the little knoll marked *c* on the map corresponding to *c* in the drawing. Along section V the land to the south rises sufficiently high to bring into view a distant ridge, quite close to the horizon line. The point *d* in the view corresponds to *d* on both section and map. The line of sight from V.P. to *d* misses the peninsula in the foreground completely, and the height EF, therefore, represents the length of the perpendicular set up at (5) in the view. The line V.P.–L (*i.e.*, the sight-line to the top of Great Orme's Head, at *e*) misses all intermediate heights between *e* and *d*, and therefore provides the only other hill profile seen from Y. At (5) on the base line of the view a vertical equal in length to EL (Fig. 6) gives the apparent height of *e*. Similarly EK, transferred to (5), marks the height of the cliff. The three points, marked one behind the other along the map section, are (as in the case of the pairs of points identified in the view across Lake Ullswater) placed in the view one immediately 'behind' the other. Section VI shows how yet a third intermediate ridge appears in the view, corresponding to the scarp which rises from the coastal plain to the south of the estuary. The Orme's Head peninsula has now sunk to trifling dimensions, but the altitudes of the three landmarks are represented at GH, GN, and GM in section VI and set off at (6) in the sketch.

Upon this plan the whole view has been based; the impression of distance is obtained by shading the view with a scale of tints proportionate in tone with the distance of the ridge or hill from the viewpoint. It may be noted how the hill at *p* rises in the middle distance to block entirely the

view into the Conway estuary and the Afon Gyffin valley. It seems doubtful whether a casual map inspection would suggest how in the same way the scarp at *q* just rises to show between the breach of the fore hills *r* and *p*. Apart from a drop at *t*, the ridge *rs* in the sketch maintains a fairly even altitude toward *s*, whereas on the map it will be seen that the actual altitude is lower in this direction as compared with that at *r*. The persistence of apparent height is due to the orientation of the ridge, which comes closer to the viewpoint, and therefore (as would occur in the real view) the height on the horizon line is maintained in spite of a slightly lower altitude. Again, the col at *t* is just high enough to block the view to the more distant ridge to the rear at *v* (see map).

Note. If the V.P. is at sea-level, then the line of the bay must be a straight line. Assuming that the V.P. is raised to a height, say, of 100 feet above the ship's deck, then the form of the bay can be plotted by drawing sight lines of *depression* rather than of elevation—*i.e.*, in this case from a height (to scale) of 100 feet on the V.P. line down to sea-level at the coast, wherever the position of the latter may fall on the section line. When the 'depression' sight line is projected out as far as the horizon line the lengths to be set off along the base line of the picture are recorded, though it must be remembered that in this case they are set off *below*, and not above, the base line of the sketch. Working on this principle, more elaborate exercises can be attempted—for example, in hill or mountain country, when the V.P. cannot be at sea-level. An indefinite number of lines of depression and of elevation can be plotted for the determination of the apparent height of both distant and near features equally as these may lie below or above the viewpoint.

It is advisable, for obvious reasons, that the vertical scale should be kept as nearly equal to the horizontal scale as is possible and within the bounds of legibility. A greater degree of accuracy is obtained by enlarging the horizontal scale to that of the most suitable vertical scale for clear work, rather than by reducing the vertical scale to that of the horizontal which happens to exist for the map.

CALCULATIONS OF SLOPE

In conclusion we may refer again to the statement made earlier in this chapter, that the actual distance traversed on the ground is slightly greater than that indicated on the topographical map by the horizontal equivalent. It is quite easy to calculate the difference between these two distances, for the H.E. and V.I. represent the base and perpendicular of a right-angled triangle whose hypotenuse corresponds to the actual surface distance which it is required to find. The V.I. is stated on the map; therefore the length of the perpendicular is known. Similarly, the length of the H.E. between successive contours may be measured, and the distance which this represents in yards or miles calculated from the scale of the map. Thus the length of the base may be found, and therefore by solving the triangle the length of the hypotenuse and the size of the angle opposite to the perpendicular (which represents the degree of slope) may be calculated.

On Map I the distance between 1 and 2 (in Grisedale) measures ·184 inches.[1] This is the equivalent to scale of an H.E. measuring 281·6 yards. The vertical interval represents 250 feet. By calculation, therefore, the actual distance on the ground as compared with the measured distance on the map is 293·6 yards. This difference of 12 yards represents an error of just over 4 per cent. on the map for an angle of slope which, by calculation, is approximately 16·9°. It is obvious from these figures that the error is practically negligible except in really mountainous country. A very useful table of errors for the map-reader is given below.

HILL GRADIENTS FROM THE CYCLIST'S STANDPOINT

Slope	*Character*	*Angle*	*Error on Map*
1 : 25	"Easy"	2° 17′	·08 per cent.
1 : 20	"Stiff"	2° 51′	·1 ,,
1 : 15	"Steep"	3° 48′	·2 ,,
1 : 5	"Quite impracticable"	11° 18′	2·0 ,,
1 : 3	"A terrifying angle"	18° 26′	5·4 ,,

[1] The distance between 1 and 2 refers to measurements (Map I, first edition) between 750′ and 1000′ contours, on the north slope of Grisedale.

For those unfamiliar with the use of trigonometrical tables, or when these are not available, there exists a very useful formula, based upon the properties of the right-angled triangle. If a right-angled triangle be drawn whose perpendicular measures 1 unit (CB, Fig. 7) and the opposite angle 1° ($C\hat{A}B$), then the base AB will be found to measure 57·3 units (cot 1°). Thus so long as $C\hat{A}B$ remains 1°, AB will measure 57·3 inches if CB measures 1 inch, or 57·3 metres if the perpendicular measures 1 metre.

But if the vertical interval be increased to a length of 2 units, while the angle of slope remains the same, then the length of the base must be increased. Thus in Fig. 7, when the V.I. is 2 units (ED), then the H.E. becomes 2 × 57·3 units in length (AD); *i.e.*, the H.E. represents 57·3 × the V.I.

If, however, the angle of slope changes (given the same V.I.), then the base becomes proportionately shorter in length.

In △ ADE, for example, ED = 2 units and $E\hat{A}D = 1°$.

In △ AFG, however, the perpendicular is still 2 units, but the angle is now 4°, and therefore the base AG is one-quarter the length of AD.

Thus the base varies in length according to the height of the perpendicular and the angle at A—*i.e.*, according to the V.I. and the degree of slope—and is equal to

$$\frac{57{\cdot}3 \times \text{perpendicular}}{\text{degree of slope}}.$$

$$\therefore \text{ H.E.} = \frac{57{\cdot}3 \times \text{V.I.}}{\text{D}} \text{ units.}$$

57·3 is not an accommodating number for

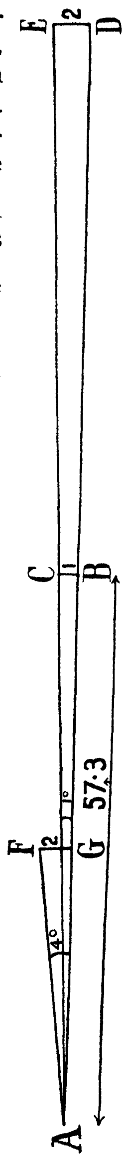


Fig. 7

purposes of rapid mental calculations, and therefore for general work 60 is substituted. Thus if the V.I. is 100 feet, and the degree of slope is 2, then the formula will read

$$\text{H.E.} = \frac{60 \times 100}{2} \text{ feet.}$$

But it is the general practice to record the H.E. in yards, and hence 20 is substituted for 60. The form in which this is generally remembered is therefore

$$\text{H.E.} = \frac{\text{V.I.} \times 20}{\text{D}} \text{ yards.}$$

Similarly,

$$\text{D} = \frac{\text{V.I.} \times 20}{\text{H.E.}}.$$

To use this latter formula, we may read the V.I. from the map as a known quantity, and calculate the length (in yards) of the H.E. by measurement; hence the degree of slope can be calculated. These estimates are relatively accurate only for gentle slopes, and never beyond approximately 20°. For more precise calculations, where slopes are steeper, 57·3 should be used instead of 60, or 19·1 instead of 20, according as the H.E. is expressed in feet or yards. The degree of slope can also be converted to be expressed as a gradient, for with a V.I. of 1, and a slope of 1°, the H.E. is approximately 60—*i.e.*, the gradient is 1 : 60. A slope of 2°, therefore, is a gradient approximately of 1 : 30; 3° a gradient of 1 : 20; etc.

It is advisable for all students to construct a scale of slopes, which may be utilized for many purposes in the course of map-interpretation. This consists in the marking off along a straight line of lengths equivalent to the H.E., drawn to scale for every degree (or half degree in the case of gentle slopes), given the V.I.

For example, on the "Popular" map the V.I. is 50 feet and the scale 1 : 63,360. Therefore

$$\text{H.E. for } 1^\circ \text{ slope} = \frac{50 \times 20}{1} \text{ yards}$$
$$= 1000 \text{ yards.}$$

That is, ·56 inch.

$$\text{H.E. for } 2^\circ \text{ slope} = \frac{50 \times 20}{2} \text{ yards}$$
$$= 500 \text{ yards.}$$

That is, ·28 inch.

$$\text{H.E. for } 3^\circ \text{ slope} = \frac{50 \times 20}{3} \text{ yards.} \quad \text{[Etc.]}$$

These lengths (as fractions of an inch in this case) are then :t off successively as a scale along a straight line. It should, owever, be remembered that this scale of slopes can be sed only on maps which have the same V.I. and horizontal :ale. If, as in the "Fully Coloured" map, there is a change the V.I., then two scales of slopes must be constructed— this case one to be used for country exceeding 1000 et in altitude (calculated for a V.I. of 250 feet) and the her for altitudes under 1000 feet, where the V.I. is 100 et.

With the aid of this piece of apparatus many geographical oblems may be solved which involve questions of gradient -*e.g.*, comparisons of gradients along main and secondary ads, etc. By practice in these and similar exercises we ay acquire the power of 'seeing solid' from the map, aim-g "to look *through* it and not *at* it."[1] Not until this stage is been attained can the real problems of geographical terpretation be dealt with.

[1] J. Fairgrieve, *op. cit.*

SECTION II

THE PHYSICAL BASIS: THE READING OF PHYSICAL AND GENERAL GEOLOGICAL FACTS

CHAPTER III

SOME ASPECTS OF THE INTERPRETATION OF GEOLOGICAL FACTS

In the examination of any topographical map it is essential that the reader should first obtain some conception of the general geological foundations upon which he may build later a geographical synthesis. If facts are to be deduced from the evidence supplied by the topographical map alone, it follows that the geological argument often will consist only of tentative suggestions, which, however, may be based on various lines of evidence. These latter include not only the evidence of the contours in portraying typical land-forms or types of erosion which are characteristic of definite geological formations, but also the additional proof which vegetation, industries or occupations, and, in some cases, place-names and types of communications may afford.

It is, of course, to be remembered that every student should possess at least a rudimentary knowledge of the general distribution and sequence of the major geological formations in their relation to the build of the British Isles, so that, having mentally located the approximate position of any topographical map as regards the major geographical regions of the whole country, he may at once have some notion of the nature of the formations which are most likely to be present in the area depicted. The facility with which interpretation of rock types can be made, and the

degree of assurance with which arguments may be developed, increases in proportion to the extent of the reader's own geological background.

Apart, however, from general geological knowledge previously acquired, a cursory glance at the topography represented should at the outset suggest the *general* character of the rocks present; for, according to fundamental laws of denudation, regions which have obviously been subjected to intense erosion, yet still remain as areas of bold relief, should be composed of relatively resistant rock. Within such areas it is often possible to identify variations in resistance. Thus where locally ridges or peaks seem equally to have withstood denudation to a greater degree than adjacent areas, the former may possibly be correlated with outcrops of even less yielding character in a region composed as a whole of resistant types. For example, it can be said of the area represented in Map XIX that relatively resistant types must prevail because of the persistence of the uplands after they have been subjected to heavy denudation (including intense glaciation, for evidence of which see Chapter VI). But the trend of the contours clearly suggests that two predominant rock types are present.

One type, to the south-east, is associated with plateau-like relief and lower altitudes, and therefore is a region perhaps composed of rock more readily eroded, a zone whose lack of abrupt ridge or serrated peak contrasts with the area adjoining it immediately to the west. The line demarcating the two relief types runs approximately south-west from the village of Trefriw, in the Conway valley.

To the west the relief is much higher, and bolder in character, and hence it may be argued that this should be associated with rocks of more marked durability. Here steep slopes tend very frequently to become true rock cliffs, which, bordering mountain tarn or larger lake, or dropping to slopes at best but thinly covered with rough pasture rather than forest or woodland, suggest a region of wild and desolate if grand relief, where the rock skeleton, or framework, is constantly protruding through a soil covering of never more than meagre thickness.

By reference to other lines of evidence it is possible to relate these contrasting units more precisely to two definite rock types. The full topographical sheet reveals the true character of the western region by the marking of innumerable slate quarries, located particularly around Bethesda, which lies in the Ffrancon valley, not far from the north-western limits of this region. The natural tendency of schists and slates to part along well-developed planes of weakness can adequately account for the presence of the innumerable cliffs, and identifies the region as one of highly metamorphosed rocks.

While the eastern plateau is lacking in precipitous edges, or the indication of slate quarries, on the other hand it is characterized by the presence of many lead-mines (see map), suggesting that here there occurs a limestone, probably of early Palæozoic age. The presence of metamorphic slates and lead-impregnated limestone indicates as a possibility the occurrence of igneous rocks in the district. Their location, however, cannot be determined definitely from the topographical map alone.

In addition to the broad application of the law of differential erosion as outlined above, one further general deduction can always be made, for by the presence or absence, sparsity or abundance, of surface waters it is possible to generalize as to the porosity of the rock. On this line of evidence, for example, the region represented in Map III may be divided into three distinct units—a central upland zone, markedly deficient in surface drainage as a whole, which separates two parallel east-to-west belts lying to the north and south respectively, where abundant surface drainage by stream or river (occasionally through pond or artificial lake) testifies to the outcrop of relatively impervious beds.

But a more detailed analysis should be attempted whereby one may try to distinguish the main types of sedimentary rocks—limestones, sandstones, and clays—a rudimentary classification, which is adequate, however, for most general purposes of map-interpretation. The varied evidence which the map provides is best considered for each of these three types separately.

Limestones

At the outset one must remember that the term 'limestone' includes all rocks containing a high percentage of $CaCO_3$, a fact which in itself guarantees solubility to be a feature common to them all. But, apart from this, individual limestones are so varied both in geological age and lithological characters that by no means does it follow that all of the criteria enumerated below are present on the map which depicts any one limestone. Further, the differences between some limestones are striking, and can be clearly identified on the map, so that it becomes necessary in addition to know how to discriminate between at least a few definite types. But at any rate some of the following considerations apply to limestones of all classes.

(1) **A General Absence of Surface Drainage.** This generally is one of the features most readily identified, as, for example, on Maps III and VI. The Wye (Derbyshire) is the single line of surface flow (Map VI) in a region of about sixty square miles. Similarly, Map III depicts a central upland belt only completely traversed by the Arun river; elsewhere, in the Lavant valley alone is there any trace of surface drainage. The restricted zone of river action results in a markedly small extent of upland dissection, which is particularly well illustrated in Map VI. Here, apart from the Wye valley, large areas characterized by non-indented contouring typify a plateau in large part quite undissected, averaging 1250 feet in altitude. Likewise, in Map III one may estimate the importance of river action as an agent of denudation when it is noted how deeply and widely the upland zone[1] is breached where actual flow has persisted (*e.g.*, along the Arun valley).

The greater elevation of the Downs as compared with adjacent plains to the north may thus be related not so

[1] Our previous knowledge of the Weald at once identifies this upland as part of the South Downs, especially in view of the frequency of the place-name 'Down' on the original Ordnance Survey map. Identification is necessary, however, by means of other lines of evidence, together with the enumeration of qualifying features, before this is assumed to be a chalk upland.

much to a markedly greater rock hardness (for their surface, unlike that of the region in Map VI, seems readily to be etched into many minor vales and ridges), as to the almost complete absence of surface drainage, which thereby limits the processes of denudation primarily to the work of atmospheric forces.

(2) **Traces of Broken or Intermittent Drainage.** This varies with different limestones. Here it is particularly illustrated on the plateau to the north of the Wye (see A, Map VI), while the very name of the river Lavant (Map III) implies that it flows intermittently.

(3) **The Presence of Dry Valleys.** This is one of the most outstanding features, which the map may indicate by means of a series of contour re-entrants characteristic in form of river valleys, within which, however, no stream line is indicated. A careful study of the contouring of the upland belt of Map III reveals how the entire topographic detail is controlled by the bifurcation and union of dry valley systems. An excellent example can be traced from the head of the Lavant valley eastward, through a series of small villages, and thence rising almost to the escarpment edge.

Fairmile Bottom (followed by one of the few main roads) is a similar dry depression. Incidentally, it is of value to note that frequently the easiest way to trace out the most pronounced dry valleys in similar upland areas is to follow the course of the main roads, which generally utilize these natural lines of easier gradient.

In Map VI, where the plateau is less dissected, the dry valleys appear to be those of a series of short tributaries. Some are only intermittently occupied by small reaches of surface flow.

(4) The **volume of rivers** crossing limestone regions is often subject to considerable variation—as, for example, where sudden augmentation from some line of underground circulation takes place. This can explain the variations in the thickness of the line indicating the Wye river. Further, the breadth of the stream line up to the very source of many of the rivers and streams which rise in limestone country is often a noticeable feature. Thus the headwaters of the tribu-

taries B and C (Map VI) may suggest in each case the sudden emergence from underground circulation of a stream of no inconspicuous volume, perhaps by means of a *source vauclusienne*—a manner characteristic of limestone rivers.

(5) **Vegetation.** In attempting to deduce soil types from the evidence of vegetation one is apt simply to consider the distribution of heath or woods, for these are indicated on the Ordnance Survey topographical maps by definite symbols. It may therefore be argued that in an uncultivated region a marked sparsity or absence of tree-growth may indicate a dry and thin soil, in keeping with a limestone surface. In the case of the Wye district (Map VI) tree-growth in its distribution seems to be closely related to water-supply. Woodland occurs almost solely in the Wye valley, and is particularly associated with the few lines of definite superficial flow of water, as in the case of the tributary valley C. The sparsity of trees on the plateau is in keeping with the previous evidence, all of which supports the suggestion that this region is one of relatively pure limestone.

The woodland of the Down belt in Map III is far more extensive, and it should perhaps be noted that, as compared with adjacent topographical sheets, where indications of tree-growth are almost entirely lacking, the present section of the Downs is far from typical; but, none the less, it affords an interesting comment on the quite common assumption that the Downs are by nature *treeless* uplands! The widely spaced symbols on the original map indicate stands of relatively open deciduous woodlands, giving perhaps a picture more typical than is often the case of the region as it appeared in early historic times. Incidentally, it may here be pointed out that the presence of superficial deposits (*e.g.*, boulder clay, clay with flints, etc.) may, by the tree-growth which they encourage, mask the presence of the underlying limestone rock, otherwise evident from the dry valleys, absence of superficial drainage, etc. This should be borne in mind particularly when attempting to identify outcrops north of the approximate southern limit of glaciation between the Thames and Bristol Channel.

It is to be remembered that absence of woodland is in

itself of no value as a criterion in deducing soil types, for in a region actually of but a single type of soil the map might quite possibly show one heavily timbered district adjacent to a treeless area, simply because in the latter cultivation has replaced forest. Therefore in regions where neither woodland nor moorland is definitely indicated the extent to which cultivation may have replaced natural vegetation should be estimated. In Map III, for example, there is little difference in the proportion of wooded to non-wooded areas if we compare the central Down uplands and the northern vale as far as the Rother, but the contrast in the number of farms per square mile is striking. Again, in the case of the plain to the south (east of Chichester) there is almost a complete absence of woodland, but correspondingly evidence of extensive farming, so that the central uplands, from the point of view of agriculture, appear to form a region of much smaller value. When it is noticed how main roads crossing the belt are unfenced until they reach the plains of more intensive farming to north and south it seems certain that the Downs represent on the whole an uncultivated zone, and the few farms that do occur may more reasonably be associated with sheep-farming and open pasturage (typical of limestones), in contrast to definite enclosed and cultivated fields on the plains. In this connexion the frequent use of the word 'wool' in the local place-names of this and other sections of the Downlands is suggestive.

The undissected plateau of Map VI is marked on the original sheet as continuous 'moor.' But the complete absence of a symbol indicating heath and coarse pasturage (which characterize sandstone rather than limestone soils) suggests that the word should be interpreted in its more general sense, to indicate in this case a region of open pasture or grassland. The sparsity of farms and the actual naming of 'pastures' in at least one instance is in keeping with the surmise that the region is one of uncultivated, thin limestone soils.

(6) **The Marking of Chalk Quarries or Lime Works, the Presence of many Place-names in which 'Chalk,' 'Lime,' etc., occur.** This is obviously direct and valuable, if somewhat 'local,' evidence, which will by no means be invariably present.

Lime works are marked on the Ordnance Survey map (Map III) near the north-east corner of the Arun gorge.

(7) **The Evidence of Population: Past and Present Distribution.** When the physical criteria indicating the nature of the soil have been collected and correlated, it is usually possible to show how the distribution of settlement accords with these. The 1-inch maps supply much archæological detail, which in some cases may be of considerable geographical significance. It is a well-known fact (for obvious geographical reasons) that primitive man in Britain tended to concentrate on upland areas, especially, though not invariably, when these were composed of limestone.[1] To-day these regions tend to abound most richly in archæological remains. Thus in the regions shown in Maps III and VI the clear relation of tumuli, camps, earthworks, etc., to the areas already surmised to be composed of limestone gives yet a further line of supporting evidence, which alone, however, is of no value in this connexion. Correspondingly the sparsity of *present* settlement over both limestone areas is normal in such regions.

It must be remembered always that evidence of this kind should be regarded as a check on former assumptions, not as an additional, quite definite proof.

(8) **Lead-mines.** Commercially lead is obtained either from veins in association with a region highly mineralized by igneous action, or from extensive replacement deposits within limestones (formed probably by the rise into cavities and lines of weakness of impregnated waters from igneous rocks situated at no great depth below). Of the two modes of formation the latter is by far the most important, and in the case of Great Britain is especially associated with cavity fillings in the limestones of Carboniferous age. Therefore the presence of innumerable lead-mines marked on Map VI may be cited as yet further proof as to the nature of this rock. In addition, this evidence is of great value in dating the limestone as one of Primary and not recent formation. In this respect the limestone of Map III may be strongly contrasted, for the Downs show no trace of metal

[1] See especially Chapters VII and XI.

exploitation. This absence, when correlated with other contrasting features, gives ground for the suggestion that the limestone of Map III is of far younger geological age.

The Differentiation of Chalk from Carboniferous Limestone on the Topographical Map. Actually Map III exemplifies the topography of chalk and Map VI that of Carboniferous limestone uplands, two of the most distinct calcareous formations in the British Isles. Although the common chemical composition has resulted in many fundamental similarities, the contrasts in the texture and structure of the two limestones can clearly be deduced from the map by the following evidence:

(*a*) *Contrasts in the Topographical Detail.* The regions in the two maps under consideration, though both deficient in surface drainage, differ markedly in the topographical detail as determined by the amount of surface dissection. Whereas Map VI depicts a region of greater altitude associated with a much larger area of undissected flat plateau, broken occasionally (whether in the case of dry valley or of river valley) by slopes that are always steep to precipitous, in the chalklands of Map III, on the other hand, there occurs a region of lower altitude, more rolling topography, with the surface *everywhere* strongly furrowed (rather than deeply dissected) by a complex dry valley network, producing here the impression of a persistently rounded rather than abrupt topography.

(*b*) *Valley Forms.* Most striking of all is the contrast in the character of the actual valleys as seen in the two regions. The Wye valley well illustrates the contouring characteristic of the mountain limestone dale. Entrenched deeply into the plateau, the valley is exceedingly narrow, with walls high and steep, as the series of contours closely following the bends of the river clearly shows. Moreover, the peculiar direction of the river-course is typical of limestone dales in general.

Turning at D by an abrupt angular bend from a predominantly west-east direction to one approximately north-south, it bends again to the original west-east direction a few miles below, at E. Tributary valleys, whether dry or

occupied by streams of intermittent flow, dissect the plateau by lines trending at right angles to the east-west main valley direction, and thus run parallel to the section DE. The whole system seems related to some influence which prohibits the evolution of normal dendritic drainage, and develops instead a distinctly 'patterned' valley network.

It may be suggested that these contrasts between the two regions (noted above in (*a*) and (*b*)) are due to:

(1) The greater altitude of the plateau (Map VI) as compared with the Down belt (Map III). This implies the occurrence of a water-table whose level lies far deeper below the surface in the first region than in the second. Where solution plays so important a part in moulding the surface features it is obvious that the proximity to the surface of either seasonal or permanent ground water is of the greatest significance.

(2) The contrasting land-forms are such as would be expected if the property of solubility (assumed to be common to the rocks of both regions) is associated in the case of the chalk with *high* porosity, in the case of the Carboniferous limestone with *low* porosity and marked rock jointing—the latter very largely controlling the direction of both surface and underground drainage. In support of these statements it may be noted how, in the case of Map VI, a localization of the drainage to follow a definite pattern has already been traced. If these directions indicate the trend of the joint planes of weakness, then major joints trend from east to west, and are cut by a secondary series which, as one would expect, lies at right angles, from north to south. These deductions are almost conclusively proved by the marking of 'rakes' (on Map VI by dotted lines). These are shown on the original Ordnance Survey map because they are known locally by distinguishing names, but their value here lies in the fact that the so-called 'rake' of the Derbyshire miners is simply a line of mineralized cavity filling, which follows the major joint planes of weakness, and sometimes, even, faults. In this section of the map it can be noted how clearly the rakes repeat the direction of the major joints, first suggested by the trend of the Wye valley.

By contrast the widespread and more irregular furrowing

of the surface of the limestone in Map III is consistent with the freer and less localized ground-water circulation which lesser joint control and higher rock porosity would ensure. (It should be remembered, incidentally, that many of the dry valley furrows which are so remarkable a feature of the Downlands have been explained as due to superficial erosion by surface streams flowing over the deeply frozen—and therefore temporarily non-porous—chalk ridges in the later glacial and early post-glacial period.)

(*c*) *The Contrast in Stages attained in the Cycle of Erosion.* Viewed as a whole, the Downs seem, by the form of the river valleys,[1] and by the more undulating and more dissected surface of softer profiles, more nearly to have attained to the stage of maturity, whereas the older limestone characterizes a region of yet youthful topography, the contrast in stage suggesting perhaps the softer texture of the chalk as compared with that of mountain limestone.

(*d*) *The Presence of Lead in the Older Limestones.* But alternatively it might be argued that there is not necessarily a contrast in the age of the two limestones according to the evidence above in (*c*). It may equally be suggested that both maps represent outcrops of the same rock type, but which have attained to different stages in the cycle of denudation. That this is not, however, the case, and that there is a real difference in the rock types, seems to be definitely proved by the presence of lead-mines in the one region (see Map VI) and the complete absence of the same feature in the uplands of assumed younger age and softer rock (see Map III). At least it may be surmised that the region where the lead is indicated is probably of Carboniferous or, it may be, earlier Primary age.

(*e*) *The Identification of Neighbouring Outcrops.* Finally, if the survey can be carried beyond the limits of the assumed limestone formation, then the identification of the adjacent rocks should aid in the dating of the limestone itself. In the case of the Carboniferous limestone, for example, it is probable (though by no means invariably the case) that association with millstone grit and coal-measures occurs as

[1] See Chapter IV for a full discussion of this.

one passes from Carboniferous limestone to outcrops of younger formations.[1] A wealth of collieries and mineral lines, the growth of an urban population, and other signs of industrialization generally locate the presence of coal-measures (though not necessarily at the surface) quite readily. In the identification of the intervening millstone grit (intermediate in the Carboniferous sequence) is involved the recognition of sandstones, our second sedimentary rock type. To these in general we may therefore now turn.[2]

SANDSTONES

We have seen how the limestone plateau (Map VI) is characterized by an absence or a minimum of surface drainage, due to the solubility of the rock. Equally it may happen that a sandstone plateau exhibits but slight dissection by river action, as a result, in this case, of the high porosity of the rock. But a distinction can generally be effected by reference to the vegetation, for, unlike the limestone, the sandstone plateau is frequently an area covered by moor and heath.

Map VIII provides an illustration. Here, north of the 550 feet contour in the west and the 400 feet contour in the east, the land rises relatively abruptly to a plateau which exceeds 1200 feet in altitude and is only moderately dissected by rivers. With the exception of the entrenched upper Rosedale and Farndale, stream erosion is confined

[1] Similarly, on maps depicting some regions east of the Pennines one may frequently identify the transition of the coal-measure series eastward into a belt of limestone (traced by the evidence of sparsity of drainage, dry valleys, etc.). But the student should generally identify this as a rock type distinct from the limestones of Primary and Secondary age, previously discussed, basing his assumptions not only on a previous knowledge of general structure and the sequence of beds in the British Isles as a whole, but also on the distinctive topographical detail suggested by the map. For this third type—namely, the magnesium limestone of Permian age—most probably will comprise a region moderate in altitude, less abrupt in profile, and often characterized by considerable farming and settlement due to a richer soil-covering.

[2] Owing to the limitations of space, it has been felt more advantageous to illustrate the method of map analysis and the deduction of geological facts by detailed observations in relation to one rock type only (limestone), leaving the student to develop from the following generalizations detailed comparisons of other rock types.

to the slopes of the plateau margin. Everywhere in this northern section there is indicated an absence of trees; but except within Farndale the symbol indicative of rough moorland pasturage is prevalent. The boundary of the moorland is particularly clear in the south, where the steep plateau margin becomes replaced by a second terrace, or lower plateau, which finally drops by yet a second steep step from an altitude of about 350 feet to the level of the plain around Kirkby Moorside (150 feet or less). The contrast in the altitude of the northern and the central plateau is of particular interest, because this change in relief at approximately 500 feet is marked by a change in vegetation—from high moorland to an upland devoid of heath or woodland, yet with but little indication of farming. The unfenced roads of the sandstone region (of lesser economic value) are replaced here by roads which are mainly fenced; and likewise the sandstone plateau moderately dissected by rivers abruptly changes to a lower terrace where surface drainage becomes deficient. Apart from slight evidence of 'broken' drainage (*e.g.*, near the farm north of the castles above Kirkby Moorside), the main rivers lie in deeply entrenched and narrow gorges—*e.g.*, the Dove and Hutton Beck, between Farndale and Kirkby Moorside. In short, both general and detailed features of relief and of vegetation point to a change from a plateau composed of sandstones to a lower terrace of limestone. The two are closely juxtaposed, and the change from one to the other is abrupt, unless the west to east line of the streams, which very persistently follows the foot of the moorland edge, indicates the presence of narrow transition outcrops of relatively impervious rocks.

But in the northern section of the region one is tempted to try to identify other allied rocks, though perhaps the evidence from the map alone is not altogether convincing. We may first recall the fact that frequently a sandstone is one of a whole series of sediments which by their order of deposition indicate that the depth of water under which sedimentation took place steadily became shallower, so that fine-grained deposits of moderately deep water become replaced by coarser grits and sands, to merge finally into

shallow water and subcontinental deposits. Thus shales are succeeded by sandstones, which again grade into carbonaceous deposits, perhaps to be represented at the present time by thin beds of coal. The latter, except where they appear as true coal-measure deposits, are rarely of great economic value, since they are only of local occurrence. They can be traced in this region, however, by the old coal-pits and disused mines marked as occurring on the plateau summit to the west of Farndale. Passing, therefore, from these assumed highest beds through the thicker sandstones which should underlie them (and identified here in the moorland plateau), one may look for evidence of the sedimentation within deeper water, typified by shales. Only where most intense denudation has occurred should these be—and, indeed, seem these to be—exposed—*i.e.*, within Upper Farndale, whose valley form is very suggestive. In spite of the apparent small volume of the Dove river there is a very conspicuous contrast between the open upper valley near Farndale and the narrow limestone gorge which characterizes the lower plateau. Thus the form of the main river valley gives evidence of two strongly contrasted rock-formations. Farndale exemplifies exactly the form that would be expected if the upper Dove had cut deeply to expose softer underlying shales. The exposure of rocks which by nature are relatively easily eroded would readily lead to considerable widening of the valley, by the persistent undermining of the more resistant overlying sandstones.

Within Farndale moorland vegetation is entirely replaced by cleared land and a few farms, traversed by fenced roads —all features which should characterize the change to the richer, if heavier, soils and more copious surface drainage of the softer and relatively impervious shale. The distinct narrowing of the valley some distance before the limestone plateau is reached suggests that the exposure of the softer series is limited as yet to the upper section of the valley, and diminishes steadily in width in a downstream direction.[1]

[1] See sheets 43 and 53 of the 1-inch geological map of England for corroboration of these surmises and for excellent illustrations of inliers formed by the dissection of an anticline by river erosion.

The assumed association of sandstone, shale, and local coal-seams within this small area epitomizes the general characteristics of the whole millstone grit formation, though in the latter the coarser sandstone beds frequently give rise to the formation of 'edges,' where often a precipitous rock face can be clearly traced overlooking the gentle shale slope below.

But the full Ordnance Survey map from which Map VIII is taken marks the region as comprising part of the North York moors of the North Riding, and therefore the dating of the varied formations becomes simple, for from an outline knowledge of British stratigraphy the student should know that the rocks of this district must be of Jurassic age.

Where commons are marked on the Ordnance Survey map it is likely that a sandy or gravelly soil occurs, especially where these are interspersed amid regions otherwise of intensive agriculture (indicated by density ot farms). Associated with the change from farmland to commons, one may also be able to trace a change in the character of the trees composing the woodlands (*i.e.*, if different tree symbols are employed on the map). Thus where deciduous growth changes to coniferous, in a region of equally low altitude, the coniferous should demarcate regions of sandy soils. Place-names in which the terms 'sand,' 'heath,' etc., are incorporated may provide additional corroborative evidence.

Clays

The identification of the remaining class of sedimentary rocks is relatively simple.

The characteristic of softness renders the outcrop of clays in general a region of low altitude and subdued relief, which a simple inspection of contours and altitude readily reveals. Similarly, innumerable streams and rivers, meres, ponds, and ornamental lakes, or, in some cases, large areas of undrained marshland, all testify to copious or superabundant surface water, whose presence can be explained by coincidence with impervious rocks. Vegetation no longer shows coniferous woodland or heath, but generally farmland

interspersed with deciduous tree-growth. In some cases, especially if porous and impervious beds are sharply juxtaposed, the margin of the clay outcrop can be traced by the presence of a distinct 'spring line,' along which, at intervals, all streams tend to rise. The marking of clay-pits, brickworks, and potteries and the inclusion of the word 'clay' in many local place-names are other lines of evidence which may often be of considerable value in supporting those mentioned above. In the light of these generalizations, a closer study of the area north of the Downs (Map IV) may now be made.

Both from the standpoint of physical and human geography the Weald affords illustration of so many fundamental conceptions that every student should be familiar with the geological formations which outcrop in regular sequence around the sandstone core of the Wealden dome. In this case the problem of geological interpretation from the map resolves itself into the search for evidence which will disclose the presence of alternating sandstones and clays as one passes from south to north across the region. Already the chalk of the Downs has been identified. The northern plain, by reason of lower altitude, may be assumed to consist of less resistant rocks. But there is clear evidence of local changes all occurring in bands of varying though narrow width which trend parallel with the Downs—*i.e.*, approximately from east to west. Map IV repeats a section of the northern plain in slightly greater detail.

(1) A small section of the chalk is included within zone 1.

(2) The steep northern slope of the Downs is lightly wooded with deciduous trees, but below an altitude ranging from 350 feet in the west to 250 feet in the east the slope changes abruptly to one of far more gentle gradient. This in general defines the southern margin of the first subdivision of the northern plain, and is demarcated approximately by the red lines bounding belt 2. That this should be distinguished from regions to the north and south, as a zone of porous but relatively insoluble rock (such as a light sandstone), may be suggested from the following evidence:

(*a*) The marked change in gradient along the foot of the

Downs suggests a change in the rock type, so that this lower slope of concave profile no longer is a part of the chalk outcrop. But that, like the chalk, it is porous is suggested by a general absence of surface drainage as compared with more northern zones. Indeed, the northern margin of this zone is demarcated roughly by the spring line of a series of streams which flow north to the Rother. Such a line (where perhaps porous beds are replaced by impervious) can be traced particularly between Heyshott and Graffham villages.

(*b*) But, unlike the highly porous and soluble chalk, which favours the rapid percolation of all water falling on its surface, the rock here permits some surface drainage. At a few points the position of the spring line has receded to the escarpment base. This may therefore suggest the occurrence of a porous *siliceous* (*i.e.*, non-soluble) rather than a porous calcareous (*i.e.*, chalk) soil.

The separate identity of zone 2 as delimited according to factors (*a*) and (*b*) becomes far more convincing when related to the remaining evidence of population and occupation.

(*c*) Coincident with this foothill zone (2) there is a very conspicuous absence of woodland of any kind, in which respect the belt contrasts very strongly with that either to the north or to the south. Everywhere tree-growth seems to have been replaced entirely by agriculture (note the farms), indicating great soil value. Equally striking is the manner in which settlement has been attracted especially to its margins, as exemplified by the distribution of villages. Considered together, therefore, these facts suggest the outcrop perhaps of a light and exceedingly fertile sandstone—both soft and porous, yet relatively insoluble—in a region providing a distinct soil type of a very considerable agricultural value (hence the complete absence of woodland). When on the larger map one traces the band farther east toward the northern end of the Arun gorge there is suggested by the close and parallel trend of the 100 and 150 feet contours a miniature but quite distinct escarpment which provides a definite topographical boundary to the zone. The hachuring on the corresponding sheet of the "Fully Coloured"

edition emphasizes more clearly this feature, which, however, can only be identified locally.

(3) Northward from the spring line (which in general forms its southern boundary) the third belt is one everywhere characterized by an abundance of surface drainage, suggesting, therefore, the change to an impervious formation. Here too is a region of farmlands, which, however, unlike zone 2, has considerable areas of woodland, all of deciduous formation. These features rather strongly suggest the presence of clays, associated with a decrease in the soil value as compared with that of zone 2. As the spring line marked the southern limit, so northward a change in the character of the vegetation brings one to the fourth and last soil type in this small region.

(4) A close inspection of the tree-symbols reveals an abrupt change from the abundant deciduous growth in the clay belt to a predominantly and closely packed coniferous growth in the succeeding northern unit. Indeed, in this last area a very large proportion of the surface is covered by coniferous woods interspersed with extensive *commons*, while farming occurs only in the small valleys. Obviously this region is one of sandy soils, in this case of relatively small agricultural value—hence the large areas of uncleared woodland and common. Coincident with the change in the type of trees is a rise in relief to a series of small knolls, revealed by a close inspection of the contours, suggesting that again the outcrop offers slightly greater resistance to the forces of denudation. The clay belt thus lies quite appropriately as a very small vale between the two adjacent sandstone outcrops. Fig. 8 shows the relation of the minor topographical features to the outcrops of rock suggested as present.

North-east of the Rother river the woodlands and commons are again replaced by many farms, and the soil type may be slightly different. But beyond noting the change, it is difficult to assign this last unit to any special rock type, since the topography in other respects seems but little altered. Long since the reader should have related the whole sequence of changes (*i.e.*, from 2, the treeless village and farm belt, through 3, well-watered farm and deciduous woodland,

thence to 4, farmland separated by heath, common, and coniferous woodland) to the geological sequence (which precedes the chalk in age) through upper greensand and gault clay to lower greensand. The accuracy of these deductions can be measured by a closer study of the red lines crossing the map, which actually mark the outcrops of (1) chalk, (2) upper greensand, (3) gault clay, (4) lower greensand (Folkestone and Sandgate beds), and (5) lower greensand (Hythe beds), the boundary line having been superimposed on the "Popular" Ordnance Survey map from the 1-inch Geological Survey sheet. If not in every minor detail, at

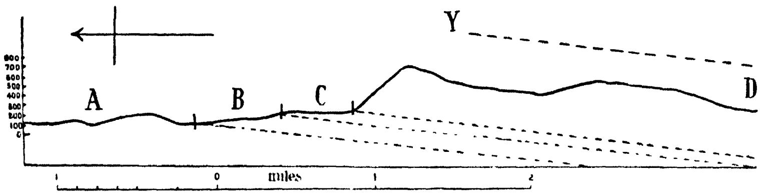


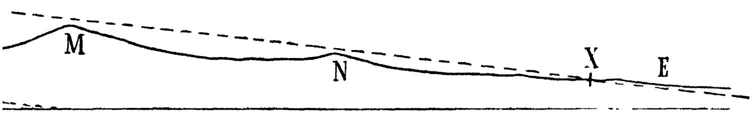
FIG. 8. GEOLOGICAL SECTION ACROSS
Based upon deductions from

least in general trend, the demarcation of soil types according to the analysis of the topographical map alone would have shown quite close coincidence with the actual geological boundaries.

From evidence of a similar character it is possible to suggest that the Tertiary clays (which we know to overlie the chalk) first appear as we descend the dip slope slightly above the spring line (which here, it will be noticed, occurs at an altitude of approximately 50 feet).

It remains in conclusion to trace from the map the evidence as to actual structure, and this is possible only in regions of known simple build. The location of the region in Map III immediately suggests a relation to the Wealden upfold. That inclined strata are present is evident from the form of the chalk upland, which affords a very clear illustration of the *cuesta* land-form. Bordering a broad northern vale, between 50 and 200 feet in altitude, the Downs rise abruptly from approximately 250 to 700 feet, to present a distinct

escarpment facing north. The slope from the crest toward the south is contrastingly gentle, and therefore may be assumed to represent a dip slope, the whole comprising an upland of asymmetrical form. Two aspects might here be emphasized, both of which check the misconceptions which text-book diagrams of escarpment formation may foster. The first is that the escarpment does not invariably present a continuous and straight precipitous rock-face. Here the crenelated contours indicate a series of alternating spurs and dry embayments, or gullies, which—at least in the case of the chalk—are typical features. The second is the form



THE REGION SHOWN ON MAP IV
opographical maps

of the dip slope surface, which, as already described, is one of diversified relief, and not of unbroken, smooth gradient. The identification of the dip slope is obviously of importance in indicating the direction of the inclination of the beds—in this case, to the south. The strike of the rock therefore lies in general from east to west—*i.e.*, at right angles to the dip—and is indicated here by the graining of the region and the sequence of narrow east-to-west outcrops in the north.

Fig. 8 represents a generalized geological section based upon the structural analysis in the preceding pages. When the approximate position of the outcrops (as determined by the evidence previously accumulated) has been plotted on the section line, it remains only to determine the angle at which the beds are inclined toward the south. This reconstruction can be attempted only where it is known that the build is of simple form, as it is necessary to assume a constant degree of inclination, which may not actually occur in the field. Speculation as to what angle should be chosen

is in many respects hazardous, but obviously must be based primarily upon calculations as to the gradient of the dip slope. Starting from the point X, where we have assumed the younger impervious rocks first to overlie the chalk, we know that the highest chalk bed and lowest Tertiary bed should here lie in contact. Now the beds of which peaks M and N are composed may lie *near* to, but probably not actually at the top of, the whole chalk succession. But, continued southward, no matter what their position in the sequence, the same beds from M and N must dip beneath the surface before reaching the point X (where the younger formation definitely occurs). Thus the line XY may be drawn provisionally, to represent a hypothetical highest chalk bed, removed by denudation. The line, dipping below the surface at X, slightly clears the summits of peaks M and N; and may be taken to show the approximate dip of the beds. To complete the section, it remains only to draw in lines parallel to the dip line XY through the points of intersection of other outcrops and section line. Though the result can be described only as approximating to accuracy, yet it is worth noting that, in spite of the very similar breadth of the outcrops B and C, the upper greensand bed is actually very thin as compared with the width of the bed below. This is the more interesting since it accords with geological facts, and thus the angle of the estimated dip line XY would seem to be confirmed as approximately correct, for it is this which ultimately has determined the width of the bed.

This chapter, dealing with more common problems, should provide the student with a working background of geological reasoning in map-interpretation. In later chapters much additional geological material is incorporated with reference to other branches of the subject. Wherever possible geological deductions should be checked on large-scale geological maps; but, as stated earlier, these are not always readily available. These pages are intended to show that the absence of a geological map need not always leave the map-reader in ignorance of all geological facts.

CHAPTER IV

GENERAL CONSIDERATIONS OF RIVER WORK

THE varied phases of river action, and many of the land-forms typical of each, can be clearly identified on a good topographical map, particularly from a study of the form of the contour re-entrant, whose variations, endless though these may seem, can be classified as typical of the phases of youth, maturity, or old age.

YOUTH

In attempting to visualize the scenery and valley forms present within the headstream section of the river system, it should first be remembered that the innumerable finer blue lines which may indicate the number of streams present in some cases give an exaggerated impression of the actual volume of surface flow of water. It is often impossible to distinguish—at least from the thickness of the blue stream line—between the smaller, but definite, streams (of narrow width, but appreciable depth and flow) and the mere trickle —practically of no width or volume—which cascades around boulders and stones in its path, occupying no valley. But the latter type to some extent can be identified by a study of the contours rather than the stream line, for if the diminutive torrent has carved no clearly defined valley, but simply occupies a slight gully or furrow down the hillside, then closely spaced contours will cross the stream line almost at right angles, showing in their trend only the slightest trace of the normal upstream re-entrant.

As the youthful torrent cuts a valley into the hillside, so the contour re-entrant becomes more and more pronounced. Successive stages are illustrated in the case of the

many small streams which course down the steep hill-slopes above the villages of Hutton and Lastingham (Map VIII). Here the map provides examples of the first stages in plateau dissection by headstream erosion and gully recession. Farndale (*i.e.*, part of the upper Dove valley) indicates more advanced stages in the same process, while the presence of relatively broad divides rather than of a narrow, closely defined water-parting between adjacent valleys characterizes a plateau still in the stages of youth. Since the youthful valley is generally of relatively steep grade (associated with the steepened upper section of the curve of water erosion),

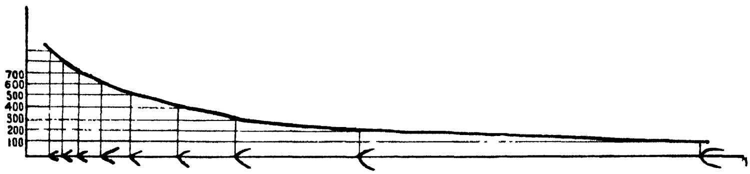


FIG. 9. TO SHOW CURVE OF WATER EROSION AND CONTOUR GROUPING

the result is that the contour lines cross the stream line at frequent intervals, while lower, in the more mature valley, the thalweg curve is flattened, so that the horizontal equivalents between successive contours become longer (see Fig. 9).

The youthful valley profile, rather than possessing a smooth curve, is more generally irregular, broken perhaps by falls. Unless of considerable height, the latter are not marked by the contours (unless the vertical interval is small), but very commonly they are named, together with rapids, because of their value as a source of power or as an attraction to tourists. This provides a sure proof that there exists an ungraded valley wherein occur local base levels (*i.e.*, at the falls)—indicating that the phase of youth has not yet passed.

The cross-section of the young valley is deep and V-shaped, and the narrow valley floor possesses no flood-plain; hence contours trend close together on either side of the stream line. Summarizing, therefore, we may say that early stages of valley development will be represented by a series of long and narrow V-shaped re-entrants spaced closely to cross the

river at frequent intervals by sharp and narrow angular bends (thereby indicating the absence of valley flats). The youthful river is primarily concerned with degradation, but irregularities—particularly in rock resistance—may initiate bends in the river-course which, once formed, will continue to develop as a result of lateral cutting on the outer side of the bend.

This feature is illustrated in Fig. 10(*a*). Here the upper

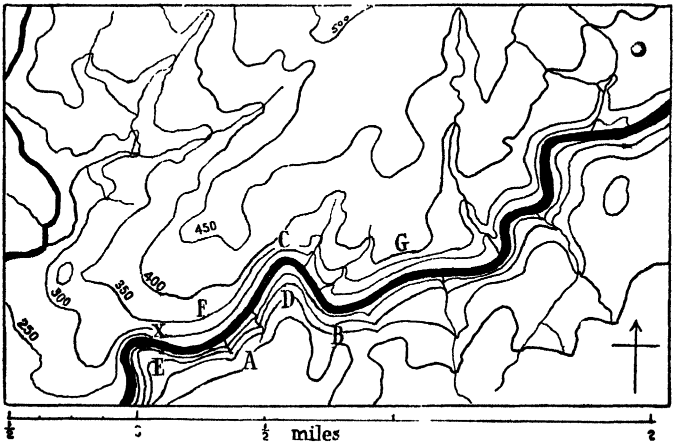


FIG. 10 (*a*). OVERLAPPING SPURS IN THE RIBBLE VALLEY (STAGE I)

From sheet 95 of the "Popular" edition. V.I., 50 feet.
Based upon the Ordnance Survey map with the sanction of the Controller of H M. Stationery Office

Ribble valley is, generally speaking, V-shaped in cross-section, but owing to a sinuous course lateral incision as well as degradation is taking place. The former occurs successively on alternate sides of the valley, and is clearly indicated by the more closely spaced contours around these outer curves (as at A, B, and C). On the sides opposing each of these points wider spacing of the contours demonstrates the occurrence of far gentler slopes. The result of this oblique rather than simple vertical degradation is the production of a typical asymmetrical valley cross-section, the steepened wall alternating in position from one to the other side of the

valley. The continued attack of the river upon one side of the valley at A, B, C, etc., is accompanied by the growth of more gently sloping spurs on the other side, at D and E, etc., and thus is illustrated the formation of one of the most characteristic features of the youthful valley, namely, *overlapping spurs*. Standing at the position marked X, no clear view up the valley could be obtained for more than a short distance. Fig. 11 (based upon calculations as to intervisibility) roughly illustrates the view which would be seen looking up the valley from an altitude of approximately 150 feet above the river-level at X.

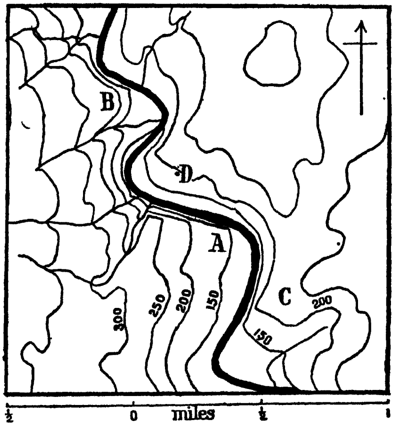


FIG. 10 (*b*). PART OF THE HODDER VALLEY (BASIN OF THE RIBBLE) (STAGE II)

From sheet 95 of the "Popular" edition. V.I., 50 feet.

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

ADOLESCENCE

But with waning youth the river passes through a transitional phase concerned primarily with the destruction of the spurs previously formed; for, as continued degradation brings decreased gradient and weaker powers of vertical erosion, so lateral cutting becomes more pronounced. This stage has been attained by the Ribble in the valley section illustrated in Fig. 10(*b*). In this second unit the contours are again closely packed against the outer river curves, though spurs, or spur relics, still remain within each bend. But that far stronger lateral cutting is present here as compared with that depicted in Fig. 10(*a*) is clearly exemplified (*e.g.*, at A) by the angular turn of each contour, indicating a sudden corner at which the gentle spur slope becomes replaced by a contrastingly steep concave curve of valley wall. This small section further illustrates how the process of spur destruction is most intensified on

the downstream side of each outer curve (*e.g.*, at A, B, etc.).

It is possible to imagine later stages of destruction—as, for example, when the crescent of close contours at A will be pushed farther and farther to the south; while, similarly, the slopes at D will remain relatively unaltered until encroached upon and undermined by the receding spur face.

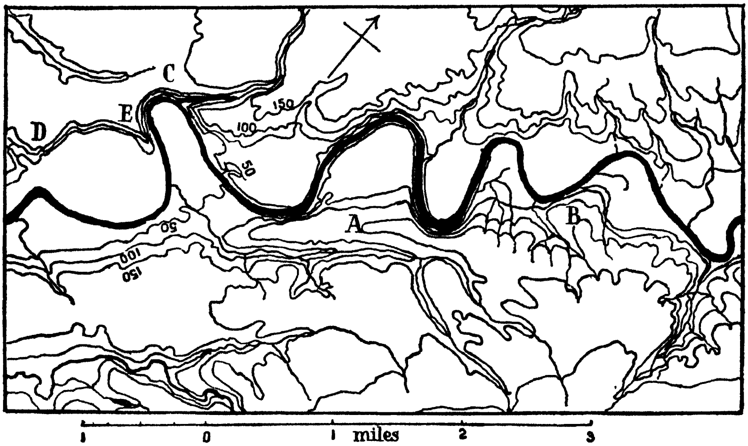


FIG. 10 (*c*). THE RIBBLE VALLEY ABOVE PRESTON (STAGE III)

From sheet 94 of the "Popular" edition. V.I., 50 feet.

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

This exemplifies the first stages in the development of distinct valley flats, lying between the abandoned spur base and an opposing meander scar, and occurring as lunate strips which alternate in position on either side of the valley.

MATURITY

Passing farther downstream, a third section of the Ribble valley is shown to illustrate a more advanced stage in the cycle of erosion. Fig. 10(*c*), representing the valley immediately above Preston, shows many features characteristic of maturity. In the first place, the gradient of the valley is

very gentle. One contour alone crosses the river-bed within this larger valley section, and aggradation rather than degradation seems more probably to be taking place. In cross-section the valley no longer has a steep V shape, but a much broader and flatter form—in some respects almost a shallow and sloping U-shaped trough. The essential difference between this section and that shown in Fig. 10(*b*) lies in the complete destruction of the spurs which characterize the younger valley form, so that a continuous, broad, and flat flood-plain has been opened. Only the bases of some

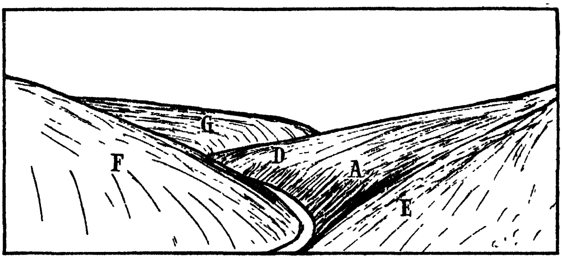


FIG. 11. VIEW LOOKING UP THE RIBBLE VALLEY FROM AN ALTITUDE 150 FEET ABOVE X IN FIG. 10 (*a*)

former spurs remain as evidence of their previous existence —*e.g.*, at A, where final and rapid destruction by river action is still taking place on either side. B may mark a similar partially destroyed spur relic. Thus we may contrast the closed view of Fig. 11 with the open, less obstructed up-valley view in the region of 10(*c*) which the development of a continuous flood-plain has produced. Here true meanders replace the former primary river-bends.

But although degradation may have ceased, the map affords a picture of vigorous erosion still progressing, so that the zenith of maturity has by no means been passed. For the meander belt fills the valley from side to side completely, and the walls are relatively steep, owing to the concentrated lateral cutting which occurs on the outer side of almost every meander bend. This is a feature most typical of early maturity, and illustrates in a striking manner the most important method of valley widening. Particularly

should it be noticed how several of the curves have cut back the wall into a crescent-shaped scarp distinctly behind the general line of the valley margin. In some respects, therefore, the relation of the river to its valley resembles that of the rapidly growing boy to his coat!

At D and E (Fig. 10 (*c*)) the valley wall shows signs of former meander undercutting in the curve of closely packed contours, though the river no longer flows at the base of the scarp. Thus whereas in Fig. 10 (*b*) the first initiation of meander scars is indicated, their full development and subsequent abandonment characterize the district of 10 (*c*).

Old Age

In Map VII the succeeding phases of late maturity and old age are indicated. The whole region is clearly one of subdued topography and slight altitude, in general not rising above 350 feet, except toward the west, near Mountsorrel, where an isolated hill rises relatively abruptly from the plain to an altitude of 400 feet.[1] The widely spaced contours indicate valley walls of relatively gentle slope, while the complete absence of contours over such large areas suggests broader flood-plains—in some parts permanently marshy (*e.g.*, between Wanlip and Rothley)—on which both the Soar and Wreak are meandering freely. Only one contour crosses the river—*i.e.*, at 150 feet, near Rothley. From here one must ascend the Wreak for at least 12 miles before rising to the 200 feet contour. Thus the actual gradient of the river bed is between 1 : 1200 and 1 : 1300! Furthermore, the form of the contour re-entrant is far less regular. It tongues upstream in a loop which is essentially broad and blunt as compared with the more youthful type previously considered.

But there are two features which especially distinguish the valleys of the Soar and Wreak from that of the Ribble (Fig. 10(*c*)). The first lies in the fact that in the Leicester district (Map VII) the meander belt is often much narrower

[1] For an explanation as to the origin of this eminence see Chapter VII, p. 149.

than the full width of the flood-plain, in which respect it contrasts with that of the Ribble, whose bends so completely fill—indeed, they might almost be said to *over*fill—the valley from wall to wall. In the case of the Soar and the Wreak it is evident that long-continued meander "swinging and sweeping" has broadened the valley up to, and beyond, the greatest width which the meander belt could attain. This width is controlled in the first instance by the river's volume, upon which factor, it may be remembered, the variations in the maximum possible radius of the meander loops depend.

The second distinctive feature lies in the form of the tributary valleys. Though the main Ribble valley (Fig. 10(*c*)) has attained the stage of maturity, the tributaries are small, and occupy obviously youthful valleys. But in the region depicted on Map VII the entire topography has attained to a later stage in the cycle of erosion, and tributary valleys equally with main valleys are of old or mature form, in some cases their broad plains widely breaking the continuity of a valley wall at best not nearly so clearly or abruptly defined.

If meander migration plays so important a part in determining the width of the valley, one is tempted to seek for traces of the movement actually in progress. An oxbow lake, where marked (*i.e.*, by a horseshoe-shaped body of water adjacent to the main river, to which one can generally trace its former relation), does afford some indication of meander movement and river straightening—*e.g.*, in the valleys of the Dove and Ure (Fig. 12). But a word of caution is perhaps necessary, for, particularly in countries where there has been extensive canalization of waterways, the straightening of the watercourse and isolation of the 'cut-off' may be features due entirely to artificial agencies. Sometimes of far greater value is the evidence afforded by parish boundaries. (These are shown on the "Fully Coloured" edition of the Ordnance Survey 1-inch map, but are omitted on the sheets of the first "Popular" edition for England and Wales.)

From a close study of many topographical sheets it will be seen that parish boundaries often tend to follow a water

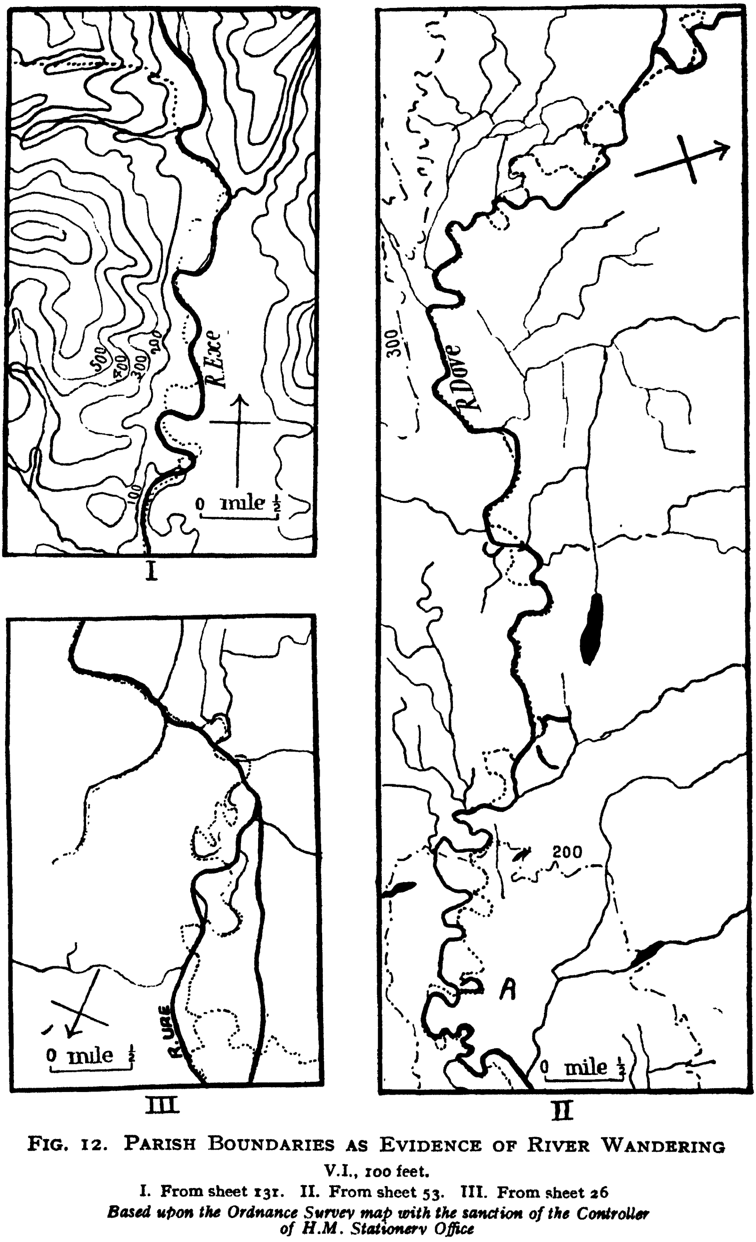


FIG. 12. PARISH BOUNDARIES AS EVIDENCE OF RIVER WANDERING

V.I., 100 feet.

I. From sheet 131. II. From sheet 53. III. From sheet 26

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

frontier, whether it be provided by a relatively large river or quite insignificant streams. These would form, particularly in early days, a clear, indisputable, and easily demarcated boundary. Fig. 12, however, shows that though the boundaries coincide in general with the present course of the three river sections depicted, they do not do so in relation to every detailed bend; yet at the same time the sinuosities of the boundary are strikingly reminiscent of river meandering; indeed, unless they demarcate the river's former course, it seems difficult to explain why such lines should have been chosen. Particularly in two sections of the river Dove, for example (see Fig. 12, II), the bends of the river and the boundary distinctly diverge. It seems likely that the suggested shifting of the river from a position formerly coincident with the boundary line is natural and not artificial, because the river is now pursuing an unstraightened course—almost as sinuous as the parish boundary line. If natural migration has really occurred here, the oxbow lake at A has been cut off and abandoned by the river *since* the delimitation of the boundary. The Exe valley (Fig. 12, I) illustrates the same phenomenon. Here the river is meandering in a broad, submature plain, bounded by walls as yet relatively steep. The discordance of parish boundary meanders and river meanders is of particular interest in this case, for not only does there seem no indication of artificial adjustments (canals, locks, etc.) to account for the discrepancy, but also the map seems to record a definite example of slow downstream sweeping of meanders, for many of the present river-bends clearly lie on the downstream side of the boundary bends. In the case of the valley of the Ure (Fig. 12, III) the variation may be due to artificial straightening and canalization of the river, of which there are many indications in the vicinity. It can only be assumed in this latter example that the boundary illustrates the normal course of the river, and that the extent of variation from this trend bears no relation to natural river migrations. We may note, however, how some of the boundary loops are still associated with threads of drainage isolated from the present river, thus corroborating the suggestion that the

parish boundary line indicates the more natural direction of flow.

The broad Dove valley exemplifies yet one further feature characteristic of the stages of maturity and old age. Apart from the main river channel, there are innumerable small streams and intercommunicating ditches draining the flood-plain surface, indicative of a plain liable to frequent and considerable floods—hence the need for the extensive drainage (both by artificial and natural agencies) of what are likely to be either completely or partially saturated water-meadows. Indeed, this suggested frequency of flood may account for the considerable and relatively rapid shifting of the river's position which the parish boundaries seem to record.

We have already noted how Farndale (Map VIII) illustrates some youthful features, particularly in the general steep stream profile and the sharp contour re-entrants which characterize this unit. But a study of the region approximately to the south of the railway-line reveals an abrupt change in the whole topography, for this comprises a district of very low-lying relief, in which adjacent meandering rivers are separated only by low and narrow divides—*e.g.*, between Hutton Beck and the Dove. Only a very small section of the larger physical unit which this typifies is illustrated here, and students should if possible consult the full sheet to appreciate the great contrast in the representation of relatively youthful and but partially dissected uplands to the north and the 'pseudo-old' plain to the south—a region of almost level, featureless relief, broken only by very slight undulations and knolls of low altitude. This area is, however, termed 'pseudo-old' because the levelness of the plain and the absence of conspicuous relief are dependent upon the exceptional physical history of the region rather than upon the normal cycle of erosion, for, as part of the plain of Pickering, it represents a section of the floor of an old lake, dating from Quaternary glaciation, and the low, isolated hillocks (*e.g.*, Great Edstone) represent the unburied summits of former hills and ridges elsewhere covered over and levelled by lacustrine and glacial deposits.

But it is possible to discriminate between plains resulting from normal processes of denudation and those—as in the case under discussion—of abnormal type. Though both may be of exceedingly low altitude and subdued relief, the region which has naturally attained to the stage of old age—worn low primarily by river action—should have an integrated drainage system, consisting of a few rivers, each of large volume, sluggishly meandering in broad and sweeping curves. Even the small section of the Pickering plain which is shown in Map VIII suggests other conditions. The full sheet yet further emphasizes the fact that there is present in many parts only a relatively incoherent drainage—a level plain threaded by many isolated and diminutive rivers, whose finely crenelated, meandering courses (*e.g.*, Hutton Beck and the Dove) are totally out of proportion to the scale of the adjacent featureless plain. It is not to their agency that planation can be due. In short, the drainage, rather than being taken as an example of old age, should here better be described as essentially youthful, where youth identifies not so much a stage of vigorous degradation as the early phases in the draining of a new plain—a region therefore initially of low relief.

The Evolution of Drainage Systems

It is essential not only to study the form of the valley in relation to the cycle of river erosion, but also where possible to identify the factors determining the evolution of the drainage system. Already the importance of rock structure has been illustrated,[1] particularly clearly from Map VIII, where the changing valley form bears an intimate relation to the type of rock traversed. In a broader way a clear relation between drainage evolution and variations in rock resistance may sometimes be traced. Here, obviously, the student's general acquaintance with the structure of Great Britain is of great assistance in the interpretation of British maps. For example, a previous knowledge of the general relationship of west-to-east consequent and south-

[1] See Chapter III.

to-north subsequent drainage to the Pennine anticlinal structure and related outcrops renders the explanation of river development a relatively simple matter when studying sheets depicting any detailed section of this region. Where the structure is more complex, however, one can generally offer only vague surmises.

Map III, which depicts a unit of simple structure, permits of close investigation. The region epitomizes in a relatively small area the well-developed, normal consequent drainage system of the Weald.

The Arun, as the main river, rises beyond the northern limits of the region shown here, but flows consistently from north to south, to cut a complete furrow through the Down uplands. Flowing thus at right angles to the line of the escarpment, the Arun follows the dip of the beds previously identified, and hence the river quite certainly may be denoted a consequent. Following the broad vale to the north of the escarpment, the Rother flows parallel to the strike of the beds and at right angles to the direction of the Arun, and hence may with equal certainty be classified as a subsequent or 'strike' river.

It is interesting to note that a small tributary of the Arun is cutting back west of Amberley Wild Brooks in a subsequent direction, parallel to the Rother. This minor valley is developed immediately to the north of the belt characterized by farm and village sites, and thus suggestively coincides with the gault clay outcrop which from other lines of evidence has been assumed to occupy this position. This minor, secondary subsequent has therefore developed exactly where it would be most expected to occur —*i.e.*, on the softer clay outcrop between the adjacent upper and lower greensand beds.

Finally, a third type of valley may be identified in this region. The many small streams which rise at the outer margin of the upper greensand bed and flow northward to the Rother will represent obsequents, for they trend in a direction which is against, and not parallel to, the dip of the beds (as in the case of the consequent Arun). These obsequents have developed only subsequently to the formation

of the Rother vale—itself, again, subsequent in origin to the consequent Arun valley.

The form of the Arun valley merits closer study, for it exhibits many features of interest. To the north, beyond the escarpment, the river meanders in an exceedingly broad open valley—indeed, the levelness of the plain near Amberley Wild Brooks is almost phenomenal. But between Amberley village and Arundel the river swings from side to side in a relatively restricted gorge, which, though of gentle gradient and flat base, is bounded by quite steep walls. The series of closely spaced, concavely curved contours which diversifies either valley wall obviously depicts meander scars, and illustrates yet again this important process of valley widening. In some cases the river is undercutting scars which are already quite conspicuously defined—*e.g.*, on the western wall, opposite to North Stoke—while in other cases the scar alone remains to perpetuate a former position of a meander loop. Thus the river is still undercutting the bank at Arundel, but immediately to the north a crescent of closely packed contours marks the position from which, at least temporarily, the river has migrated.

Southward, beyond Arundel, the river flows over an open and low plain (see full Ordnance Survey sheet), so that, in trenching through the broad upland belt of the Downs, the river valley exemplifies the form of a water-gap which is consequent rather than antecedent in origin—*i.e.*, a gap which was formed by a consequent river whose direction (and hence also the position of the gap) was determined by the folding of the Wealden dome; while the cutting of the gap has occurred contemporaneously with the etching out of the escarpments and vales (the latter with the aid of subsequent tributaries). This type of water-gap differs fundamentally from that to be discussed later, where the gap is formed by rivers which are perpetuating a much older direction of flow antecedent to the formation of the high ridges which they now breach (see Map XII and Chapter V).

Had we a larger extension of Map III it could be seen how the lower greensands, north beyond the Rother, rise to a lower and less regular escarpment, which again faces north,

and is breached (though in a less spectacular manner) by the upper Arun river, to form a minor water-gap through a ridge of lesser altitude.

River Capture

A region within which there has been so clear a development of consequent and subsequent drainage should lead one to search for signs of encroachment by subsequents, so that adjacent weaker consequents are beheaded. Of this there is definite evidence. The Lavant river rises midway down the dip slope of the chalk uplands, at an altitude just below 200 feet, and though of comparatively small volume it flows in a valley of moderate width, trending parallel with the course of the Arun. It is thus at once identified as consequent in direction. But the river has cut no deep water-gap through the chalk, owing, doubtless, to its restricted drainage basin (and therefore so much smaller volume). That formerly it possessed a far larger catchment area is clear from the contouring of the adjacent Downlands to the north. For the headwaters of the present Lavant lie at the meeting of two distinct dry valleys, one of which leads from the eastern summit of the Downs in a general east-to-west direction through the series of small villages, while the other (an equally conspicuous land-form) leads due south from the escarpment summit, here only 300 feet in altitude. The dry breach of the upland margin is the more significant when it is noted how to east or west from this col the land rises quite abruptly to heights of 700 to 750 feet, which altitude is maintained with but few minor breaks over a considerable length of the escarpment summit. The col at the head of the Lavant dry valley illustrates the form of a wind-gap, in this case marking the cleft cut by a former Lavant river of far larger size, which probably rose beyond the northern limits of the area shown in this map. At this time the Rother must have been of considerably shorter length, not having receded by headward erosion as far as the basin of the neighbouring Lavant consequent.

Since the height of the gap represents the approximate

level at which the Lavant flowed before it was depleted of its headwaters, the Rother vale (at least in the west) will have lain at approximately the same, if not a slightly higher, altitude.

The height of the escarpment at the wind-gap should, then, represent the depth to which further dissection and the etching out of the northern plain has proceeded *since* water ceased to flow through this once embryo water-gap, now left high and dry above the plain. The escarpment likewise may have been lower in altitude—at least, considered relatively—for, on the assumption that no change in sea-level has occurred, the plain then lay perhaps at an altitude of 300 feet in the west (*i.e.*, the height of the wind-gap), in contrast to a present altitude in general of less than 200 feet (and often well below 100 feet). Actual summits would, however, have been higher, for sub-aerial denudation must have lowered the surface since the date of river diversion. Furthermore, when attempting to reconstruct the topography before capture took place one should remember that the escarpment then lay to the north of its present position, though how far north it is impossible to say.

Slow retrogression of the scarp is, however, always taking place as denudation eats into the dip slope; indeed, we may note here that it is this action which accounts for the present width and the position of the chalk outcrop as an outermost rim within which are exposed successively older and older rocks.

Though in this map there is an absence of direct evidence of escarpment recession, this can sometimes definitely be identified. For example, the small section of the Cotswold escarpment illustrated in Fig. 13 shows two circular knolls rising abruptly from a low, flat plain and separated from each other and the escarpment face by a distance of some miles. Their shape is typical of similar outliers that together, from their marked alignment, identify former positions of the old escarpment front. These are hills of 'relict' origin.

But to return to the study of the South Weald drainage, it must be remembered that at the time of river diversion, although the gorge of the Arun would not have been trenched

to its present depth, yet it was probably cut to a distinctly lower level than that of the Lavant, for thus would there be provided a favourable gradient for relatively stronger head-stream erosion by the Rother—an essential condition if the Arun was to gain supremacy over the Lavant. It is possible to develop an argument from the map to explain why the

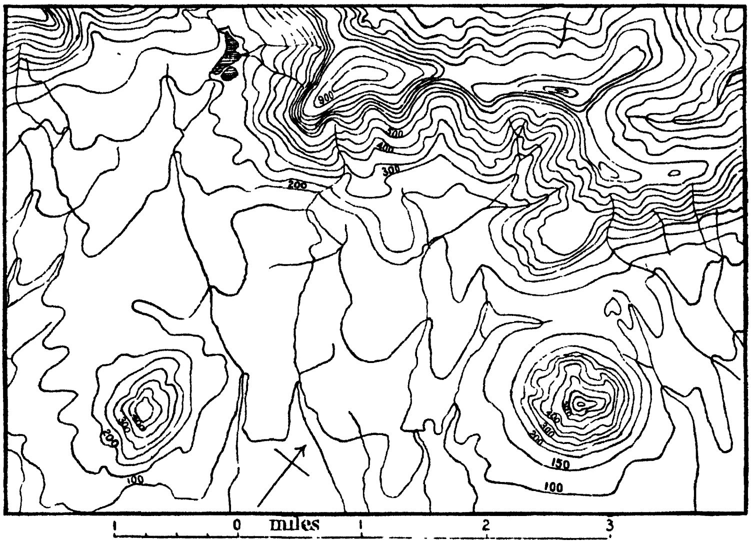


FIG. 13. MAP TO SHOW ESCARPMENT RECESSION

From "Tourist" map of Cheltenham district. V.I., 50 feet.

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

Arun should have degraded its bed more rapidly than its western neighbour in the earlier phases of river activity. At the Arun gap the Down belt is only 4 miles wide; westward, however, quite suddenly it increases in breadth, and at the Lavant valley it is fully 6 miles wide. Trenching through the chalk (of all Wealden rocks the one most resistant to the forces of denudation) in that section where the outcrop is so distinctly narrowed, the Arun possessed a strong initial advantage over the Lavant, less favourably placed. That the strength of the former river has resulted from (and

is not the cause of) a narrowing of the chalk belt seems clear when it is noted to how small an extent the Arun valley (in common with many similar water-gaps to the east) breaks the continuity of the escarpment line. If—as one might suggest—the variations in the width of the outcrop should be related to more rapid escarpment recession in the vicinity of stronger river action, then one would expect to find the water-gap coinciding more nearly in width and position with the entire major escarpment embayment.

Immediately to the north of the wind-gap, at the foot of the escarpment, there rise two streams which flow to join the Rother at, or near to, Midhurst. The longer of the two is one of the few obsequents to rise actually within and not on the northern margin of the village and farm belt (assumed to represent the upper greensand outcrop); thus here the spring line curves back toward the escarpment base. This is of interest if we relate the position of these two streams to the former consequent drainage through the Cocking Pass. With the etching out of the Rother vale, and therefore the establishment of a slope to the north rather than to the south, these present obsequents—even though of relatively diminutive size—may possibly represent reversed consequents—a common product of river capture. The result, therefore, of all these changes is to leave the Lavant to-day as a beheaded river—a 'misfit' of small and perhaps even no volume, at least in the drier season. Only the very pronounced cleft on the skyline of the ridge testifies to its depleted energy and former importance.[1]

In passing, it should perhaps be noted that the flat floor of the Arun gorge, with its countless drainage ditches, and also the expanse of remarkably featureless and equally waterlogged plain to the north of the gorge (Amberley Wild Brooks) are accounted by Clement Reid[2] as due to extensive silting by muddy tidal waters ponded back within and beyond the gorge, and entering thus far formerly as a result of relatively recent subsidence and partial drowning of the

[1] The student should draw a section along the crest-line of the escarpment, from east to west, through the wind-gap.

[2] Clement Reid, *Submerged Forests* (1913).

South Wealden gaps. But though they are so clearly depicted, it is beyond the scope of map-interpretation to offer an explanation as to the origin of these features, other than that markedly flat and waterlogged plains of this type always suggest that heavy and recent aggradation has taken place, in this case to an abnormal degree.

River capture may occur in a more direct manner, as the result of the conflict of two main streams, without the aid of any intermediary subsequent tributary (as was necessary in the example from the South Weald). Particularly is the second type of capture liable to occur where two rivers are cutting back from opposite flanks into the same upland divide. Headstream diversion in this case is generally identified by means of the characteristic 'fish-hook' bend which the aggressive river develops; and this becomes no uncommon feature on maps depicting the more maturely dissected uplands, where the indeterminate water-partings which characterize the phase of youth have become narrowed, and are fought for in close combat by rival streams.

A clear example can be read from Map IX. Here the Feshie burn, which below X flows to the north-west, has captured the headwaters of the Geldie burn—a river which flows in a direction diametrically opposite, to the eastern Dee valley. X marks the position of the 'elbow of capture' —in this case, a very pronounced turn. Above this bend the Feshie continues, in both general gradient and direction of flow, the valley of the Geldie, from which it is actually separated at X by a distance not exceeding 350 or 400 yards. It is possible that the river Eidart also at one time flowed eastward into the Geldie rather than, as to-day, into the Feshie, for its upper valley trends eastward toward the Geldie. If this is also an example of river diversion, it must have preceded the capture of the Geldie headwaters at X, for the Eidart would be tapped by the Feshie at an earlier date, as the latter cut back into the plateau by headstream erosion.

As in the Wealden example, the discussion of river capture must not rest merely at identification of the phenomenon. It is necessary to attempt to account for the greater

powers of encroachment possessed by the Feshie burn. The 1500 feet contour marks in both the lower Feshie and Geldie burns a distinct change in the general character of the valley gradients, and the lowest level for practical purposes which is common to both sections of the valleys shown in this map. We may therefore theoretically regard this as a local base-level, to which the upper section of each river system is degrading its bed. When the distance between X and the 1500 feet contour is compared in both valleys, then the reason for the supremacy of the Feshie becomes clear.

According to the law of unequal slopes, the stream of steepest gradient (and hence highest velocity) possesses the greatest powers of headstream erosion, and will therefore cut back more rapidly into the uplands behind. In the case of the Geldie, the drop from X to 1500 feet is spread over 7 miles, but in the Feshie valley the same fall occurs in 3 miles. Therefore the Feshie should become the aggressor owing to the contrast in the stream gradients—a feature which is easily appreciated from a comparison of the horizontal equivalents along each stream line between successive contours. The complete absence of a divide suggests that capture at X is of very 'recent' occurrence (note how closely the 1750 feet contour re-entrants approach to each other). But it must not be assumed that every example of diversion identified will show only a low col of this type or, indeed, that the cause of diversion is necessarily related to processes of normal capture alone, particularly in glaciated regions. In this case it has been shown[1] (1) that the tapping of the Allt Coire Bhlair, Eindart, Eidart, and Geldie was definitely a pre-glacial phenomenon; (2) that glacial erosion largely modified and obliterated the valley forms produced by capture, though the full extent of this is now masked by subsequent fluvio-glacial deposition; (3) that late glacial deposition, particularly in the vicinity of the present divide, diverted the Geldie headwaters by overflow to their present

[1] Dr Bremner, "The Capture of the Geldie by the Feshie," in the *Scottish Geographical Magazine*, 1915. See also "Geographical Study of the High Plateau of the S.E. Highlands," in the *Scottish Geographical Magazine*, 1919.

course to the Feshie, in this way perpetuating a far older capture system. Characteristic of glaciated regions, the full story is not so simple a one as map-interpretation alone would suggest.

Whatever the nature of the diversion, it may be suggested that the Feshie will continue the active degradation already in progress below the bend at X, and therefore continued headstream erosion will result in the incision of the upper Feshie into its older, more open, and gently graded valley. This process will be indicated on the map by deep contour re-entrants extending from the lower valley to bend far upstream into the Feshie headwaters, just as at present they bend in deep V's into the Eidart valley from the lower Feshie. Similarly, the beheaded Geldie will become incised below its present level in the course of normal degradation; but this will occur at a less rapid rate as compared with the entrenchment of the Feshie, because of both its depleted volume (hence diminished erosive power) and its initially gentler gradient. But ultimately the double process will result in the creation of a divide, so that the low col of to-day becomes a 'nick' left in a ridge overlooking the future river valleys some considerable distance below (just as the Cocking wind-gap now lies high above the Rother vale).

Note. The student should construct imaginary contour maps to show the relations of the Geldie and Feshie rivers (*a*) at some earlier period, preceding the capture of either the upper Geldie or the Eidart; (*b*) at a future time, when headstream erosion has considerably altered the present conditions, and the col at X marks the position of a wind-gap some height above the river-levels.

CHAPTER V

REJUVENATION

The Form of the Incised Meander

In the previous chapter reference was made to the representation of features typical only of the normal cycle of erosion. It remains to identify the land-forms that give evidence of rejuvenation.

We should remember that rejuvenation may occur either locally (within a limited portion of one river's course) or generally (*i.e.*, characterizing many of the river valleys over a wide area), according to the factors which cause renewed degradation. It may be best to begin with a study of the latter—*i.e.*, general rejuvenation—where regional uplift has occurred to a considerable extent over an area which had previously reached an advanced stage in the cycle of erosion.

Some of the best maps for the purposes of this study are the topographical sheets of the United States Geological Survey, where, on a scale of 1 : 62,500 (*i.e.*, approximating to the British 1-inch Ordnance Survey scale), relief is shown by contours at a vertical interval of only 20 feet. Maps X, XI, and XII are prepared from typical sheets of this series.

Again, as with other aspects of denudation, it is the contouring of details of valley forms which gives the surest, and generally most obvious, indication of rejuvenation. One of the easiest of land-forms to identify on the map (and often most characteristic in the field) is the incised meander. Now this feature may be produced to a markedly varying degree, and from the contour map alone a great deal can generally be suggested as to the stage reached in its development and the processes involved in its formation. Variations in the form of the meander and of the spur which the river loop encloses depend to a large extent on the relative

rates of the lateral and vertical erosion taking place. We should always remember that though rejuvenation primarily involves *down*-cutting, meandering none the less implies considerable *lateral* cutting, a point which, though obvious, it is easy to overlook and which, too, is of especial importance in the interpretation of some land-forms.

In Map X the contours between 1250 feet and 2500 feet follow closely round the meanders and curves of a river, on both banks, so that we can visualize the watercourse as being entrenched in a narrow, steep-sided, V-shaped valley —a typically youthful form. There are no valley flats present, still less a broad flood-plain in keeping with the extent of the meander swings; in fact, where we should most surely expect to find alluvial flats (*i.e.*, between the meander loops) there are bold spurs extending out from the flat plateau-like uplands, averaging 2250 to 2500 feet in elevation, and falling relatively abruptly to the river-level, which is in many cases 500 feet below. If in imagination we fill in the trench in which the river lies, and visualize a river flowing at the summit elevation of approximately 2250 feet, we should then have a normal mature river meandering in a broad, gently graded valley, for the contours, once above the elevation of 2250 feet, are exceedingly widely spaced. It is this incision of the present valley into the upper open valley, and the presence of such well-developed meanders in spite of the obvious V-section of the valley, which establishes rejuvenation as a certainty.

A comparison of the contour spacing on either side of the valley at any one point shows that there is relatively little difference in the lengths of the horizontal equivalents. The valley is therefore comparatively symmetrical in form. This suggests that down-cutting has been proceeding far more rapidly than lateral cutting by meander swinging, for the latter would have caused a steepening of the slope (and hence a closer spacing of the contours) on the outer side, and corresponding lessening of the gradient and wider spacing of the contours on the inner side, of the meander curves. In the region shown in Map X there will have been some lateral movement, but this is not marked as compared with

the amount of vertical erosion which has taken place since uplift.

In Map XI there are other examples of incised meanders, but here incision has been accompanied by the development of an asymmetrical valley section, and there is clear evidence of much more lateral river-shifting as down-cutting has proceeded than was the case in the region of Map X. The present meanders by no means occupy the same position as when degradation was first renewed. On the inner convex side of the bends we can trace by the wider contour spacing the steady shifting of the river away from the spur as degradation has proceeded, while correspondingly on the concave outer bends the river is encroaching into the wall behind, in many cases destroying the spur. This results in exceedingly closely packed contours—*e.g.*, at the base of spur B and opposite to and below spur A (Map XI).

The contouring indicates, therefore, a steep slope and a gentle slope opposing one another at any one point on opposite sides of the valley, and at the same time steep and gentle slopes alternating with each other along the same valley-side. This is reminiscent of the similar alternations in slope (and therefore in contour grouping) associated with the young river valley, in the development of overlapping spurs,[1] though in the case of the rejuvenated valley the differences of slope are associated with true meanders rather than with primary river-bends.

We can trace all stages in meander spur evolution as the spur becomes more and more narrowed at its base (*i.e.*, where the spur first extends out from the undissected land). This narrowing is obviously due to lateral undercutting on adjacent sides of the neck (see particularly spur A on Map XI). It is noticeable, too, that where such excessive narrowing is taking place, the concentration of lateral erosion tends to lower the spur at that point. Thus the upper contours become broken, not passing completely round the spur, but each forming an isolated ellipse broken from the spur base. (See contours for 800 feet, spur A, Map XI.) It is obvious that though vertical entrenchment is still proceeding, finally

[1] See Chapter IV.

the neck of the narrowed spur may be completely broken through, if lateral swinging is sufficiently strong; the course of the river will then become straightened. What will be the contour evidence that such has occurred? An example can be traced on Map XI.

The first indication most probably will be an unexpected straightening of the river-course among a series of more or less regular meander bends. Now between meanders A and B (Map XI) there is certainly a stretch which is unexpectedly direct. Furthermore, between *x* and *y* there is a crescent of fairly closely packed contours, clearly resembling a meander scar, and facing a narrow depression which slopes from both the *x* and the *y* side toward the present river. (Note how the contour line for 700 feet tongues up toward this flat from both sides.) If the river originally followed the curve suggested by the meander scar, it would have formed a meander that would fit in radius and direction between the present river loops around spurs A and B. Perhaps the most interesting feature—which adds certainty to our interpretation of the river's old course—is the relic of spur which stands as an isolated, elliptical shaped hill, surrounded on three sides by a narrow, low-lying plain and on the fourth side by the present river-course. Actually on the original sheet from which this example is taken the contours are shown for every 20 feet rise, and the spur relic stands out most vividly, represented by a series of concentric oval contours. It has been necessary to interpolate some of these contours (shown by dotted lines), for the spur does not reach to a height of 100 feet above the river-level. It can be suggested, then, with some assurance, that the old course followed from *a*, approximately through the points *b*, *c*, *d*, and *e*, before the old spur was broken through. For any suspected case of river straightening by this process the map should show examples of all the foregoing features.

Fig. 14 apparently shows the same phenomenon in all stages of development. At A there is a spur approaching the stage of truncation, and at B there appears to be an exceptionally clear example of the completed process. The spur relic is left as a rounded hill rising from the river-level at

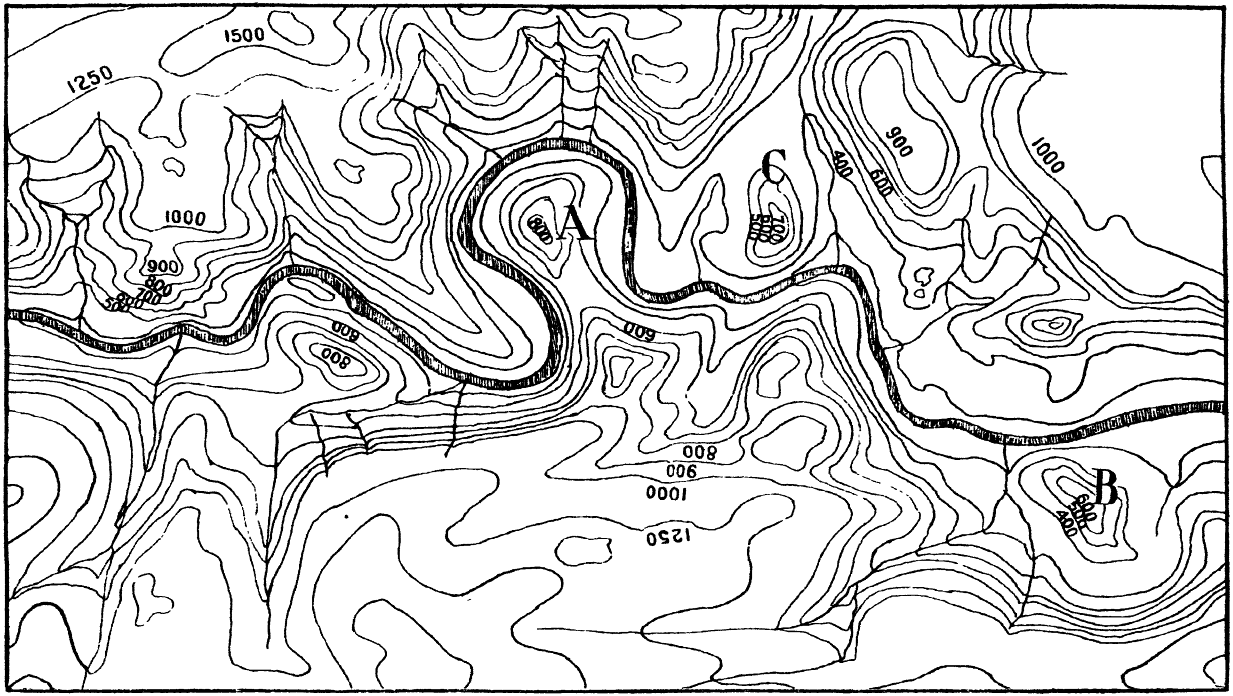


FIG. 14. PART OF THE DEE VALLEY (LLANGOLLEN)

V.I., 100 feet up to 1000 feet: 250 feet above 1000 feet   Scale, 1 : 63,360 approximately.

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

400 feet to a height exceeding 600 feet, and overlooks a crescentic flat which is drained to-day by small streams from either side. The latter, again, is backed by a very plainly marked meander scar. At C there is yet another example, for here too is the isolated hill fronting on the one hand a narrow crescentic flat and, on the other side, a relatively straight stretch of river. It is interesting to note how similar in altitude are the summits of the spurs and spur relics (between 700 and 800 feet). These, we may suggest, are in all likelihood relics of the original plain over which the river meandered before incision took place.

But, admirable as this is as an example of the contour forms, it affords an illustration of the care which is necessary in assuming facts from map evidence alone, for though the map gives a picture of conditions when completed, it does not tell the whole story of stages passed through in their formation. We are correct in suggesting the presence of incised meanders and that the isolated, rounded hills are relics of broken or truncated spurs; but we are wrong in this case in suggesting normal river action as the agent effecting the truncation. The cutting of the gorges through the spurs took place in late glacial and post-glacial times, when overflow channels crossed the neck of the spurs, at a time when the whole winding Dee valley was blocked with ice and drift, facts which the map alone cannot tell us.[1]

In addition to the oxbow upland and relics of spurs, we should look for traces of meander scars, which may not only be well above the present river-level, but probably also show little relation to present meander curves.

Valley Flats and Spur Destruction

In the valley studied on Map XI there is practically no valley flat present, the river being bounded on the one hand by a steep side and on the other bank by a much gentler slope. These conditions indicate that the river has not

[1] For details as to the evolution of the valley see L. J. Wills, "The Late Glacial and Post-glacial Changes in the Lower Dee Valley," in the *Quarterly Journal of the Geological Society*, vol. lxviii (1912), pp. 180–198.

ceased degrading its bed, for the meander swinging as down-cutting proceeds simply results in further extension of the spur as the steep wall bounding the opposite bank recedes. The double river action might be likened to that of a saw working obliquely rather than vertically.

Now if vertical down-cutting had ceased, or practically ceased, then the continued lateral swinging would result in the meander migrating away from the spur in a relatively horizontal direction, so that the spur would then cease to grow outward in length, although the undermining of the concave bank might continue. We can identify regions where this stage has been reached, for then an area conspicuous in its lack of contours extends round the base of the spur. Obviously the development of these valley flats is intimately connected with the destruction of the previously formed spurs, and we should notice carefully how far the map shows stages in the development of the new at the expense of the older land-form.

Map XIII, showing part of the Wye valley below Hereford, illustrates not only the development of valley flats, but also the way in which spur destruction is primarily effected by the concentration of maximum cutting on the *downstream* side of the concave bends, thus exemplifying the two types of meander movement, lateral and downstream.[1] The student should pick out examples of this feature on the other maps included in the envelope, and also construct contour maps to show further stages in the elimination of the spurs, and the final stages, when an open valley with a continuous flood-plain replaces the forms indicated above.

We have studied the incised meander in some detail, because it is most essential to realize the many stages of physical history and river work which the contour forms may indicate; and it is in the *valley* contours that the most convincing evidence of rejuvenation occurs. We may turn, however, to other aspects of contour interpretation, particularly related to the identification of areas which have been subjected to regional rejuvenation after previous peneplanation.

[1] The same feature is exceptionally well shown on the Rouen sheet of the 1 : 200,000 map of France.

The Form of the Uplifted Peneplain

One might be tempted to estimate from the contour altitudes the amount of uplift which has taken place, and here a word of caution is necessary. It might be suggested, for example, that the actual difference between the altitude of the present river-level and the spur summits represents the amount of uplift which has occurred, but it is just as misleading to give such a measure as the precise amount of uplift as it is to suggest that the actual original peneplain is represented on the map by the gently undulating surface in which the meanders are entrenched. Subaerial denudation has been lowering the surface, even though working so much less rapidly than concentrated river action. Thus, reading directly from the contour numbers, we most probably under-estimate the total amount of uplift which has occurred (assuming the region previously to have been planed to an advanced stage in the cycle of erosion).

It must be remembered, also, that the uplifted peneplain will have been subjected to differential erosion, so that any outcrops of harder and more resistant rock will subsequently stand out as residual elevations. A study of the contouring of any such residual heights may provide clues as to the structure of the old peneplained area.

We may turn back for a moment to Maps X and XI in illustration. The incised meander present in both regions suggests rejuvenation, but in the first area, when we have climbed to the summit above the incised river, we encounter open and relatively featureless relief. This is very plainly indicated on the whole sheet of which Map X is a small part; but it is noticeable even in this small section in the wide spacing of the contours above 2250 to 2500 feet. The complete absence of residual elevations suggests a uniformity of rock hardness over the old planed surface which may imply the uplift of a region of relatively horizontal sedimentary rocks.

From Map XI it is evident that the uplifted area above the incised meanders is diversified by relief features of varying magnitude, which take the form of well-marked ridges

trending in a direction approximately parallel with the main and tributary river systems, and broken only by water-gaps where the rivers cross them. Examples of small water-gaps are seen at C and D (Map XI), but better examples on a much larger scale are shown in Map XII. These water-gaps, it should be remembered, are quite distinct in origin from those examples illustrated previously in the Weald (see preceding chapter).

A further study of the region between the main meandering river and the ridge FF (Map XI) shows that the old peneplain is here represented by alternating minor ridge and valley, the ridges rising to an elevation of 1100 to 1200 feet, and maintaining a moderately even elevation and direction. If these represent outcrops of relatively resistant rock (and the trellis or gridiron pattern of the tributary drainage is suggestive of this), then the old peneplain must have been crossed by outcrops of rocks alternating in hardness, and occurring in continuous bands trending approximately from south-west to north-east.

Particularly when adjoining sheets are studied, it may be argued from the map that the even summit of any one ridge, and the fair coincidence in the altitude of one ridge with others, gives reason to suggest that it is the difference in altitude between the valley floor and the even summits of these ridges (rather than the meander spur summits) which represents more nearly the relative amount to which the old peneplain has been raised above base-level. And, furthermore, we cannot say that the altitude of these even summits represents the *actual* uplifted peneplain level, for since uplift occurred the height of these ridges must have fallen, if only slightly, under the influence of weathering.

On many sheets of the Central Appalachians it is clear that a series of ridges, rising to a very much greater height above the minor ridge and vale relics of the peneplain, forms even more outstanding topographic features. In most respects these greater ridges show exactly the same characteristics, but on a very much larger scale. In Map XI, for example, the ridge FF is portrayed as rising to a height of 2100 feet, towering high above the minor ridge peneplain

level of 1100 to 1200 feet. The same features can be seen in Map XII, where, however, the two comparable levels are much lower; *e.g.*, the major ridges, attaining to an altitude of approximately 1300 feet, stand on an upper plain about 500 feet in height.

A glance at even the small sections illustrated in Maps XI and XII shows how remarkably continuous, regular in form, and strikingly similar in summit elevation these higher ridges are. Map XI shows how the rivers trend parallel to these features in general direction, until (as depicted in Map XII) they cross the ridges at right angles to them, by the great clefts or water-gaps previously mentioned. Particularly should the close contouring round the ridges at the gaps be noticed, indicating an extremely abrupt rise from the river-level. The broadening of the river as it crosses intervening tracts between the ridges clearly indicates the alternation of outcrops of hard and soft rocks. It is almost possible to argue that the marked uniformity of upper ridge levels (which the map so plainly indicates) is suggestive of yet an earlier cycle of denudation, and therefore that the upper surface of these major ridges may perhaps represent the ridge relics of yet an older peneplain—*i.e.*, ridges which in the earliest phase of peneplanation stood out only as features of relatively slight relief. Where, as in Map XII, the river cuts through the major ridges it may represent the perpetuation of the same drainage direction across the harder outcrops through at least one phase of rejuvenation before that which has caused the present incision of the rivers.

We have considered here only the two cases—where there are either no residual elevations or simply the ridge type; but the student must be prepared to find elevations of all kinds, and, moreover, individually they may vary considerably in altitude if composed of rocks varying locally in hardness and resistance. In such cases it is the valley evidence of incised drainage on which the identification of rejuvenation must entirely depend.

Finally, we should notice whether the map shows any indication of the relation of drainage to structure. This is particularly obvious in the two types of regions shown in

Maps X and XI. In the former the structure, which we have assumed to be of simple horizontal rocks, has resulted in a normal dendritic drainage system, while in Map XI it may be seen that the alternation of ridge and vale has produced a very marked trellis system, seen not only by the trend of the main rivers parallel to the high ridges, but repeated in miniature by the tributaries, as in the area around C and D.

In conclusion, it should perhaps be noted that river terraces, which frequently are so characteristic and well marked a land-form in the field, are by contouring seldom to be identified, unless on maps of a scale too large for consideration as topographical maps. Generally speaking, from the point of view of map-reading, their identification may be ignored.

Local Rejuvenation

The land-forms associated with rejuvenation may occur either regionally or locally. We have seen that it is often easy to identify this phenomenon when it occurs regionally, but a much closer inspection is often necessary to reveal what might be called local rejuvenation within an area of apparently normal drainage. Furthermore, when identified, it is often exceedingly difficult, on the map evidence alone, to account for but local occurrence. The example already described from Fig. 14 is a case in point, for immediately to the west of this section of the Dee valley one enters a normally glaciated district, while immediately to the east the incised valley leads to a relatively open plain of quite slight relief, in which traces of incision now but feebly show. In this case it can only be argued from the map that the incised section of the valley cuts across a bold ridge of relatively high elevation (presumably, therefore, of harder rock), within which the record of incision is still perpetuated, whereas to the east it has been destroyed in the area of lower altitude and of assumed softer rock. The difficulty of explaining the map evidence is emphasized by the frequent association of local rejuvenation with superimposed drainage dating from a much earlier phase when perhaps the base-level and superficial rocks were very different from those

of the present day. In map-reading, therefore, we must frequently content ourselves simply with the identification of the phenomenon, and not attempt an explanation of its presence, though there is often opportunity here for the ingenious and observant student to construct possible solutions.

In one case, however, it is normal both to expect local rejuvenation and to explain it fairly readily—namely, in the region recently glaciated. It is particularly characteristic of regions in which post-glacial modifications have replaced the discordant grades of ice-worn valleys by the normal smooth curve of water erosion. But a study of the contour indications of those features is best left to the following chapter, where it more properly belongs.

CHAPTER VI

THE INTERPRETATION OF GLACIAL PHENOMENA

Erosion

U-valleys. The contouring of the main valley depicted in Map XIV offers a strong contrast to that of valleys studied hitherto. In the Upper Rhone valley the spacing of the contours bounding the valley-sides suggests a steepness of slope which one associates with very youthful topography. Yet the valley floor, broad, and of very gentle gradient (crossed only by one contour), is characteristic of maturity.

The main river, meandering over a partially waterlogged flood-plain, is obviously not degrading its bed in this section of the valley, and, indeed, seems remarkably small in comparison with the width of the valley floor, so that the river might well be termed a misfit. It is impossible to accredit the widening of the valley to normal processes of lateral river erosion; indeed, there is no trace of a meander scar, for the contouring of the valley margins is represented by straight and parallel lines—at least through a considerable vertical range along each valley wall.

Truncated Spurs. But approximately above 2100 metres there is a change in the type of contouring to indicate a form particularly well developed on the north-western valley wall—*i.e.*, in this case on the right-hand side of the map. Above 2100 metres the contours are curved to enclose, between valley re-entrants, typical outward bends reminiscent of the spurs of the youthful valley system. Below approximately 2100 metres each spur front is replaced by a blunt façade which clearly indicates the truncated spur. It is this truncation which determines the topographic form of the valley, and gives an open, U-shaped section characterized by unobstructed views down the length of the

valley. These associated features depict a typical product of ice erosion—the U-shaped valley.

On the left-hand wall, above a height of roughly 2100 metres, the valley-side slopes at a distinctly gentler gradient; identified by the change in the lengths of the horizontal equivalents above this altitude. On the right-hand side this is less clearly indicated, for headward erosion by tributary torrents has more deeply furrowed the valley-side. But where these small tributary torrents are absent (*e.g.*, above Obergesteln), there the right-hand wall shows the same distinct change in gradient approximately above 2100 metres. Thus the typical section of the glaciated valley in Alpine regions is fully shown to depict a deep U-shaped trench sunk within upper terraces of more gentle profile, the latter perhaps comprising the relics of a floor probably ice-worn in earlier phases of the glacial period. The student may perhaps be reminded here of the importance of considering Alpine land-forms as the product of both fluvial and glacial agencies, the two forces having succeeded one another in regions which were alternately laid bare to the attack of running water in inter-glacial time and covered again by ice in glacial periods. In identifying and explaining the origin of 'benches' and bench relics, it seems especially important to bear in mind these climatic fluctuations and their influence on contemporaneous denudation.[1]

(Since the whole question as to the efficacy of ice as an agent of erosion is subject to some difference of opinion, students should acquaint themselves with the opinions of both schools of thought which are current before attempting to identify and estimate the part played by ice from the evidence of the topographic map alone. Text-books by American physiographers in general lay emphasis on the power of ice to over-deepen and excavate the U-valley trough. The possibilities of an alternative explanation are summarized by Professor Garwood in an article in the *Geographical Journal*, vol. xxxvi (September, 1910), entitled "Some Features of Alpine Scenery which may be attributed to Relative Ice Protection." De Martonne, in *Traité de*

[1] See W. B. Wright, *The Quaternary Ice Age*.

Géographie Physique, vol. ii (fourth edition, 1926), gives a valuable and balanced exposition which, while paying attention to the nature of denudation in inter-glacial times, does not under-estimate the erosive power of ice, nor lose sight of the importance of pre-glacial topographical detail in influencing the way in which ice may subsequently mould the scenery.)

Benches. Map XVI, A, illustrates some of these details even more graphically. The Vorder Rhine valley possesses a similar flat, waterlogged, and gently graded floor, with *un*-indented steep valley walls. The upper benches within which the valley is entrenched are very pronounced, in this case rising from the trough summits (approximately 1100 metres) to an altitude of about 1400 metres on the southern side, above which the gradient again steepens (see cross-section, Fig. 23).

Map XVI, B, illustrates yet further the detail typical of many Alpine valley-sides, exemplifying especially well how the valley wall may be steepened by pronounced lateral ice planation. The steepest slopes are clearly differentiated from gentler terraces by the absence of forest on the latter. The reader should endeavour to visualize the detail and the formation of this topography. The map shows only a small section of the flat Rhone floor and the steep southern valley wall, but it is clear from the contouring that the Rhone Glacier, when ploughing down the valley, has by lateral erosion planed back the valley-side to truncate the lower slopes of the tributary valley along the line AB. This explains the abrupt corner at which each contour turns, indicating strongly contrasting degrees of slope as one turns, say, from A first toward the main valley and then to the tributary valley. Of equal interest are the very small terraces of relatively gentle gradient surrounded above and below by precipitous slopes (*e.g.*, at C). A glance at the full combined sheet Visperthal, from which the map is taken, reveals the presence of many similar isolated terrace fragments of variable size and width at approximately corresponding altitudes along the Rhone wall. These fragments evidently represent relics of a floor of the Rhone Glacier when the latter was cutting at a higher level. Thus C, for

example, may represent the depth of the Rhone valley (and hence the level tc which the ice must at least have cut) in the last but one (*i.e.*, third) glacial period. In the following inter-glacial period (according to one point of view) *river* action cut down lower, to a level near to, or as deep as, the present floor of the main valley. In the subsequent fourth glacial period ice filled—or, it may be, overfilled—the new lower valley, and by the process of lateral planation (involving the truncation of spurs) moulded this deepest section into a U-form. Only locally, as at C, has the combined activity left undestroyed relics to perpetuate former valley levels. Post-glacial retreat of the ice has therefore revealed the characteristic Alpine profile of alternating terrace and steepened, step-like drops. At least in the analysis of Swiss sheets—if not of British sheets—the student should look carefully for examples of this feature, and notice the extent to which such relics may persist at a fairly constant level on the opposing valley walls.

It is important to estimate from the contour map the extent of post-glacial modifications within the ice-worn trough. Characteristic land-forms may readily be identified in Maps XIV and XV. Thus the cross-section of the well-glaciated Lonza valley (Map XV) is almost V-shaped rather than U-shaped, owing to a widening on each side of the valley of the horizontal equivalent between the lower contours, which *outcurve* in sequence toward the centre of the valley. In the field there is ample evidence of the existence of those very features which the map suggests—namely, the occurrence of alluvial cones, tapering high up the valley wall on its south-eastern side. Converging one into another, they form a protective and continuous mantle decreasing the normal steep gradient. In large measure they may represent the deposit of redistributed scree or landslip material in part brought down by the agency of streams or melting snows, etc.

Yet a more complete picture of post-glacial stream action may be read from Map XIV, which especially exemplifies the importance of gradient in relation to deposition and erosion. On the right-hand valley-side a series of torrents

has cut back deep gullies and even gorges in coursing down the glacially steepened valley wall, thereby diversifying the topographic detail very considerably. The abrupt change in gradient at the valley bottom has led to the growth of extensive fans or dry deltas. These are distinguished from the cone by contour bends which are more widely spaced and of greater circumference, therefore indicating a flatter cone profile and more gentle gradients—*e.g.*, at Münster (Map XIV). Again, the continuous sequence of the contour bends suggests confluent 'delta' growth. Far less stream recession, and correspondingly smaller cone or fan formation, seem to occur on the opposite valley-side. Though the contrast may be due to differences of rock texture, it may equally reflect the contrast in solar influences. For the side which faces the sun should at an earlier stage in post-glacial time have been free from protective snowfield or stagnant ice, since when—seasonally, or even diurnally—it has been exposed for longer periods to the attack of running water; hence the greater extent of valley modification.

The straight, parallel, and closely packed contouring of the U-valley is generally the feature most conspicuous and readily identified upon maps of glaciated mountain districts. But generally there are other land-forms depicted whose combined presence gives equally good reason for the suggestion that the scenery of to-day has been determined largely by the 'recent' presence of ice. Turning to Map XIX, we may note in the first place the U-shaped cross-section of the main valleys, similar in form (though on a rather smaller scale) to the Swiss valleys. The Vale of Conway exemplifies, particularly on its western side, the work of ice erosion. The floor of the valley is also typical in its breadth and gentle gradient. It should be noted, however, that the vale as a whole lacks perfect symmetry, for the eastern wall (except toward the south) is less steep than the opposing western flank. A study of the full sheet reveals how this is in keeping with the contrasting topography eastward beyond the vale. That glacial moulding should develop such different gradients on opposite sides of the same valley seems clearly to suggest that ice erosion has in this case pro-

ceeded along a zone demarcating the junction of contrasting rock types. It is unlikely, however, that the trough will have been excavated entirely by ice erosion, for differential denudation most probably had etched out the zone long before the advent of glacial times. The trough is probably a pre-glacial valley only superficially moulded to become U-shaped by ice action. With this should be compared the cross-section of the Nant Ffrancon valley below Llyn Ogwen. Here the excessively steep valley walls equally overhang the flat valley floor, and there is no evidence of contrasting rock formations outcropping on either valley-side.

Hanging Valleys. The discordant grade at which tributaries meet the main valleys is one of the most characteristic features of glaciated mountain topography. Examples of this phenomenon, together with stages in its destruction, are illustrated by many of the Conway tributaries entering from the west—particularly north of Bettws-y-Coed. In its most perfect development the hanging tributary may be visualized as occupying a valley U-shaped in cross-section and gently graded, until at its junction with the main valley it drops by falls, often of considerable height, to the level of the main river below.

But generally to-day the vertical drop is modified in height, largely as a result of the changes wrought by the stream itself in post-glacial time, and it is of no little importance to bear this in mind when identifying the hanging valley on the map. Fig. 15 illustrates diagrammatically the profile and contour grouping for a hanging valley which has undergone no post-glacial modification, and it will be clearly seen that the contours cross the lower tributary valley as straight lines. This, together with their close grouping, indicates that the stream occupying the upper valley drops precipitously over the steep wall. Only above the main U-valley trough do the contours tongue upstream, as in the normal glaciated valley. Thus, since the contours become closer rather than more widely spaced in a downstream direction, the law of normal river valley contouring is reversed. But the falls at F mark only a temporary base-level, checking down-cutting above this position. There will be concentrated erosion at this

point, so that a niche is steadily cut both backward and downward into the wall below as the height of the falls is steadily diminished. Fig. 16 shows stages in the destruction of the hanging lip, and the changing profile as the discordant grade of the thalweg in the ice-eroded tributary valley is steadily replaced by a curve of water erosion cut in rela-

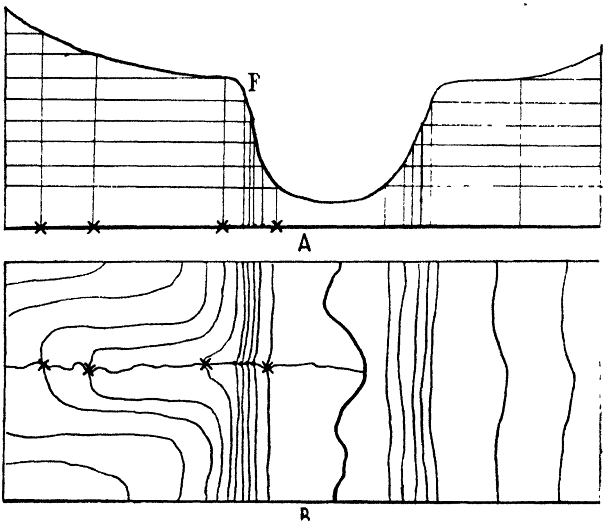


FIG. 15. *A*, DIAGRAMMATIC SECTION, *B*, GENERALIZED FORM LINES, TYPICAL OF A U-VALLEY AND HANGING VALLEY

X—X = H.E. in both section and map.

tion to the base-level provided by the main valley floor. Obviously when curve 6 has been attained (Fig. 16) the evidence of ice action (as far as the hanging valley is concerned) will have practically vanished, and the contours which hitherto crossed the lower valley walls in straight, unindented lines will then tongue upstream in deep re-entrants for long distances. The reader may now turn to Map XIX to trace actual examples of these stages in the evolution of the tributary valley.

We may ignore at the outset those small mountain torrents which merely cascade down the over-steepened valley-

side without carving a gorge. True examples of hanging valleys which have suffered modification to a varying degree do occur in the case of the rivers draining from Llyn Eigiau and Llyn Cowlyd, and, farther south, in the valleys above the village of Trefriw and opposite to Llanrwst.

Considering first the valley above Dolgarrog, it may be noted how, between an altitude of 100 and 600 feet, the wall over which the river cascades has been subject to but little modification and the river has carved no valley back into the hillside. Here, therefore, the valley still hangs over

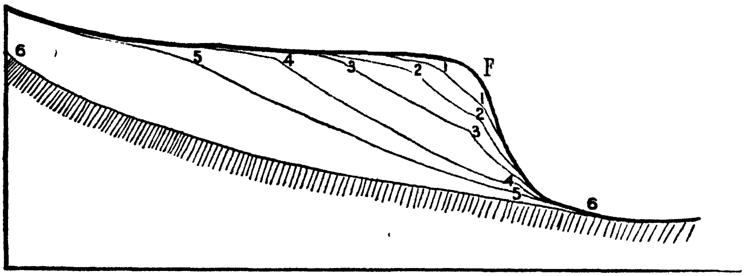


FIG. 16. DIAGRAM TO SHOW STAGES IN THE DEVELOPMENT OF A NORMAL PROFILE OF WATER EROSION FROM THAT OF A HANGING VALLEY

the deeper Conway trough. But above 600 feet the contours tongue upstream—at first rather sharply—to an altitude of 800 feet; this therefore perhaps marks the position where the lip of the valley has been cut down and the old falls lessened in height. Above 800 feet the valley opens into a relatively broad U-shaped trough, indicating the former position of a small tributary glacier. Above 1000 feet the width of the valley is remarkable in relation to the size of the stream. The gradient is correspondingly excessively gentle up to the back of Llyn Eigiau (and the headstream to the south-west), where slopes become very much steeper. Near the extreme head of the valley the bounding walls rise at least to 2300 feet.

The valley to the south is of similar form. Below 800 feet the gradient rapidly increases until again the tributary is truly hanging at an altitude of about 400 feet. Falls are

in this case actually marked and named. The tributary valley at Trefriw possesses no hanging lip, which latter (assuming that it once existed) is entirely replaced by a relatively youthful gorge. As headstream erosion cuts more and more deeply, so these contour re-entrants, already quite long, will recede yet farther and farther into the upper, gently graded, ice-worn valley, ultimately to mask completely the former U-shaped cross-section of the valley.

The Llugwy, a river of much larger volume, has cut a more normal profile, but in any case (according to the argument of those who attribute hanging valleys to the unaided and very considerable erosive powers of ice) the much larger Llugwy Glacier which once occupied the Llugwy U-valley would more nearly, if not completely, have cut to the level of the Conway valley. Hence this tributary may never have overhung the main valley to the same extent as the more northerly and much smaller tributary valleys, occupied by ice of lesser volume. Therefore post-glacial modification by river action can more rapidly establish a normal gradient in the lower Llugwy valley, though the presence of falls still indicates the need of further readjustments in the stream profile.

The reader must expect to find on Swiss maps examples of far more stupendous gorges, which replace the lower ends of much larger hanging valleys. Owing to the difficulties of map reproduction, the sections of Swiss maps selected to be shown here in no way adequately suggest the magnitude to which Alpine land-forms may attain. We may, however, note that the lower Münsterthal (tributary to the Rhone, Map XIV) is of very steep gradient, and deep contour re-entrants tongue so far up the valley as to suggest at first glance that the valley has been cut entirely by river action. But the valley walls at higher altitudes are precipitous, and it is clear that the present gorge has been incised into the normally flat floor of a tributary hanging valley whose lip is now entirely removed. The same history may explain the relation of the lower Eginen gorge to its upper valley, of which only a small part (again U-shaped in section) is depicted here.

The Lonza valley (Map XV) itself comprises part of a hanging valley, whose floor as a whole is not yet dissected by post-glacial changes. Deposition, as previously noted, has modified the valley flanks. The lower end of the Lonza river is, however, only very slightly incised into the floor (see shading), and this marks the extreme upper end of a deep ravine, by which in the course of a few kilometres the

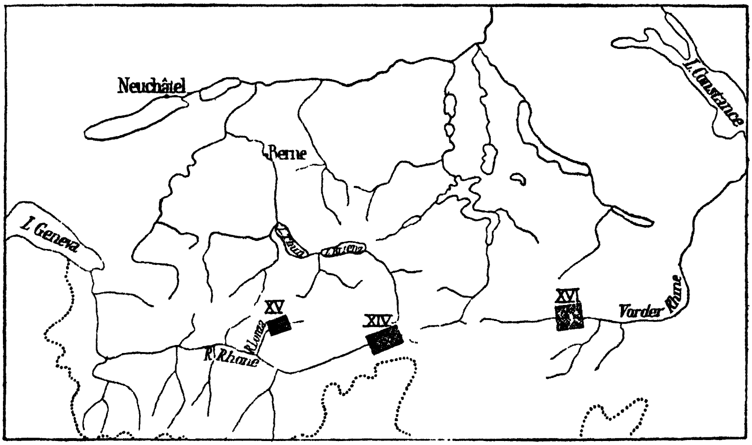


FIG. 17. SKETCH-MAP TO SHOW RELATIVE POSITIONS OF MAPS XIV, XV, AND XVI OF THE ATLAS

river plunges down to the Rhone valley, some 700 metres below. Steadily the gorge has been cut back upstream to this present upper limit. One can visualize the changed contouring at some future date if the gorge cuts back to the head of the valley. A comparison of the cross-section of the valley might be made for sections sited near Ferden and at Ried, illustrating the changes—constructive and destructive in nature, and typified by the alluvial cone and incised gorge.

It is now more easy to follow some of the changes which have occurred in the river systems discussed from Map IX, for the diversion of the Geldie burn depicts simply a common glacial modification in regions of glaciated topography. The Feshie and Geldie burns formerly occupied hanging

valleys tributary to the deep U-valleys into which they now flow. Post-glacial river erosion to a certain extent has cut back the gorges from the 1500 feet level of each U-valley, and these have partially receded into the upper valleys. The influence of ice erosion in causing very steep and very gentle slopes to occur in close proximity frequently causes post-glacial river capture, for examples of which the student should always be prepared. In the present case, as noted earlier,[1] the full story is not evident from the map alone, since in late glacial times final diversion resulted from the presence of fluvio-glacial deposits within a system already modified by pre-glacial capture.

Corries. On Map XIX the head of many tributary valleys is marked by a semicircle of closely packed contours, often replaced by the symbol which indicates true rock precipices. This circular wall overlooks in many cases a relatively flat or gently undulating subcircular plain, not infrequently masked by the presence of a lake more or less rounded in outline, while below, on the remaining side of these rock-girt amphitheatres, the land drops rather less steeply. A remarkable series of these hollows flanks the south side of the Nant Ffrancon; most of the basins are drained by small rivers. Equally characteristic examples occur at A, B, and C, and also above the lake-head at D. From transverse and longitudinal sections in each instance an 'armchair' shape may be recognized, and from this the land-form becomes readily identified as the cirque (or corrie, cwm, etc., according to varying nomenclature). The example at E clearly exemplifies the enlargement of the corrie basin as a result of the persistent recession of the cliff wall. Here the contouring shows how, from the occurrence at one time probably of only a small hollow, a receding cliff has steadily cut away the oval-shaped ridge. The continuation of the same process will lead to the shattering of the whole ridge.

The corrie is often first identified by the subcircular lake so commonly present in these basins. The lake proves the existence either of a true rock basin—probably over-deepened

[1] See p. 89.

by ice erosion—or, it may be, water, impounded behind a dam of morainic or scree material. But the lake is a transitional feature, and may rapidly become drained. Then (as in the case of the U-valley or the hanging valley) post-glacial river action may empty the hollow, and finally cut down into the old and relatively flat lake-bed. In this connexion we may contrast the form and degree of preservation of the flat and relatively extensive plain at E with those, more dissected by rivers, overhanging the Nant Ffrancon valley.

Arête. The close proximity and number of the corries overlooking the latter valley has led to the development of a feature especially important in Alpine scenery—namely, the *arête*. From the evidence of the map the origin of this land-form cannot be mistaken. Corries which doubtless were once separated by pronounced divides are now isolated only by narrow, knife-edged ridges. These have been formed by the continuous recession of adjacent walls under the influence of frost action, so that, finally meeting back to back, the sharpened edge replaces a former broad divide. Any further regression will lead simply to the disintegration and breaching of this last ridge—in many cases to form single larger composite basins.

Irregular Valley Profiles. An important contrast in the work of the glacier as against that of the river is the power of ice to erode unevenly, and to produce a profile of very irregular gradient, which by definite local over-deepening may be reversed in direction for some distance. It should be possible to identify this aspect of ice erosion on the topographical map. The irregular profile of the tributary valleys which overlook the Vale of Conway has already been discussed. Particularly, in the present connexion, one may notice the changes of gradient between Llyn Eigiau and Dolgarrog, and again in the tributary valley below D. The presence of lakes Z and Y above the 'steps' (which occur between altitudes of 400 and 600 feet) is very typical; indeed, the whole valley, beginning as it does in a cirque basin, epitomizes almost all of the essential features in the topography of the tributary Alpine valley.

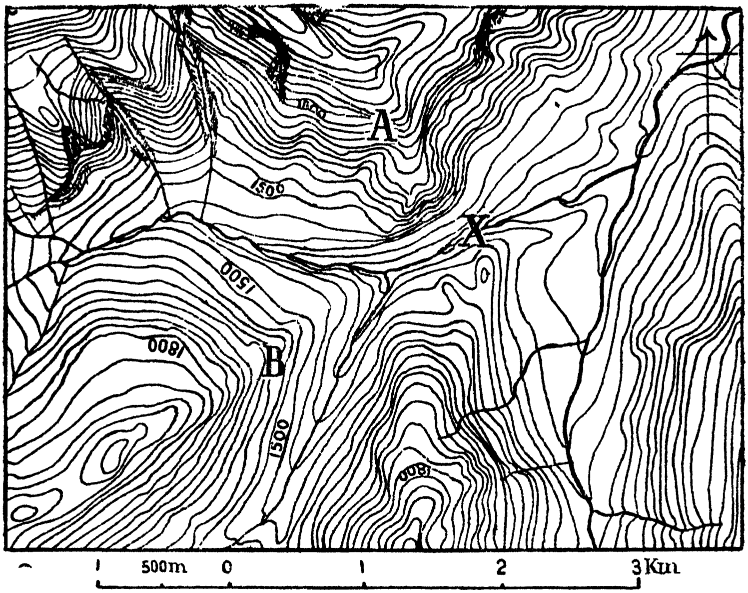
(1) *Valley Steps.* The much larger Nant Ffrancon and

Llugwy valleys exemplify similar irregularities of profile, for in both cases long and exceedingly gently graded flats alternate with steep reaches, or steps. The step may be identified by the close grouping of contours locally, as, for example, where they cross the valley immediately below Llyn Ogwen in the Ffrancon valley, and above the village of Capel Curig in the Llugwy valley. Particularly in the case of the former example is the trend of the contours very characteristic, for they cross the valley in a series of blunt bends, contrasting with the narrow, pointed re-entrant which one associates with normal river erosion in mountainous districts.

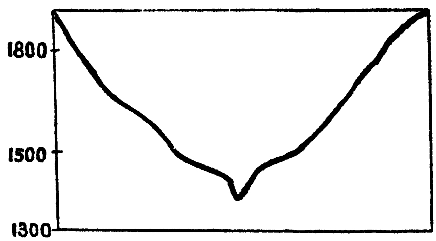
It yet remains to suggest some reason for the occurrence of the step, since it is a feature which may be due to one of several factors.

In the case of the step at Capel Curig, the sudden rise occurs just above the point where the formerly glacier-filled valleys of the Gwrhyd and the Llugwy converge. This may therefore afford an example of the over-deepening of the lower valley due to the greater excavating power of the ice when reinforced in volume from the Gwrhyd valley glacier. But it seems impossible to suggest that the same explanation may be given for the step in the Ffrancon valley, for there is no convergence below the step of a similar glaciated valley, and it seems unlikely that the local supplies from the corrie basins to the south would provide sufficient increase in volume to effect the over-deepening of the lower valley. The step may possibly demarcate changes in rock outcrops, so that differential erosion has led to the over-deepening. In this case the presence of Llyn Ogwen immediately above the step may point to slight differential erosion as the cause of over-deepening just above as well as just below the step, which latter may then coincide with a sill of resistant rock crossing the valley. A study of more detailed topographical and also geological maps is necessary, together with close field investigation, before these surmises become of any value. As they stand, they merely illustrate the scope of map analysis. When the valley step has been identified on Swiss maps, it is interesting to try to relate the altitude of this

land-form to that of the alp and bench relics in adjacent districts, in an attempt to reconstruct former levels and to



Based upon part of Blatt 463, "Adelboden" (Switzerland).
V.I., 30 metres.
Reproduction permitted by the Service Topographique Fédéral, Berne, Switzerland, September 7, 1928



Generalized section between A and B.

FIG. 18. STEP DISSECTION

test Professor Garwood's view as to their relation to relative ice protection during inter-glacial time.[1]

[1] *Op. cit.*

One may trace stages in the destruction of steps in the main valleys comparable to those within the hanging valley and corrie. These often show interesting examples of local rejuvenation, and cause abrupt alternations in the character of present river action within one and the same valley. For whereas in the longer flat sections the river may be meandering sluggishly over the U-valley floor, yet in another section it may be engaged in cutting a deep gorge through the step; and as this gorge recedes into the flat upper valley above, so incised meanders may be developed. Fig. 18 illustrates a stage in the destruction of what may have been a step or rock barrier within the valley. Above the point X deep, narrow contour re-entrants seem at first glance to suggest that normal water action is the factor which has alone determined the topographic detail. But particularly when the valley is viewed in cross-section the origin of the feature as a local incision of a water-worn valley within an older U-shaped trough becomes clear.

(2) *Lake Basins.* The irregularity of profile in ice-worn topography is especially revealed in the characteristic profusion of lakes. The more or less circular corrie lake has already been cited, but there are many other equally definite types which may be identified from the map. The most conspicuous lakes of glacial origin are those which occupy the relatively long, narrow basins to form ribbon-shaped expanses of water, which in general possess relatively straight margins, determined by the even side of the U-valley itself. These lakes either may occupy a true rock basin formed by the local over-deepening of the old glacier-bed or may simply represent the ponding of water behind morainic barriers blocking the lower valley. The depths of lakes and their submarine contours are not shown on many older British topographical maps, and hence the true form of the hollow can only be suggested from other somewhat indirect and less certain lines of argument. These are chiefly related to (*a*) the shape of the lake, (*b*) its position in relation to estimated directions of ice-flow, (*c*) the extent to which the hollow has been destroyed by post-glacial river action.

For example, the valley glacier which originally ploughed

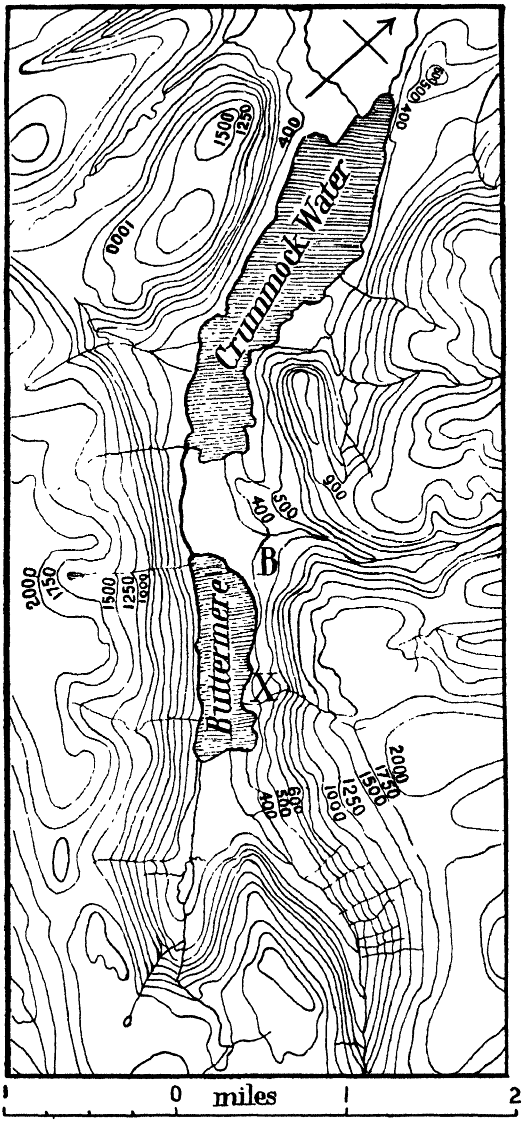


FIG. 19. BUTTERMERE AND CRUMMOCK WATER

From sheet 12 ("Keswick and Whitehaven") of the "Fully Coloured" edition.
V.I., 100 feet up to 1000 feet; 250 feet above 1000 feet.

Based upon the Ordnance Survey map with the sanction of the Controller of H M. Stationery Office

down the U-shaped trough now occupied by the lakes Crummock Water and Buttermere (Fig. 19) was restricted between walls rising to an altitude exceeding 2000 feet, until in the north, as the map shows, the valley opened to a wider plain. As the glacier deployed out laterally when beyond the restriction of the valley, so compression of ice, and therefore intensity of vertical erosion, would decrease. This, then, may have led to the over-deepening of the valley relatively to the northern plain, and hence the present lakes may occupy true rock basins. Equally it may be, however, that extensive moraine was deposited across the valley where the mountain glacier emerged to the plain. (In their relation to general configuration, and perhaps likewise in their origin, these lakes seem to epitomize the conditions which have led to the formation of some of the far larger basins in the lower Alpine valleys.)

It remains to consider whether or no the two lakes lie in separate, glacially over-deepened basins, divided by a rock sill. The evidence of post-glacial modifications suggests that a single basin, originally much longer and continuous, has been shortened and divided by the growth of tributary deltas (*a*) feeding into the upper end of Buttermere lake, (*b*) growing across the valley at Buttermere village. The extent of lake elimination wherever tributary streams debouch on these temporary base-levels should always be noted. Like the alluvial fan, and unlike the gorge, it is a post-glacial modification of constructive rather than destructive character. It should be noted, further, from Fig. 19 how even the small torrent at X has built out a small delta into Buttermere, while at B the strength of the deltaic growth has been sufficient to restrict the channel connecting the two lakes to the extreme opposing valley-side. The apparent rapidity and ease of lake elimination would support the contention that the lake basin is relatively shallow.

Returning to the study of Map XIX, we may suggest that once there existed a lake of far larger dimensions, extending back up the Nant y Gwrhyd—hence the extent of marsh flats above the present lake. The latter seems to

be relatively shallow, for it has almost been divided by a small dry delta, probably composed of scree fragments falling from the cliffs above, since no river flows into the lake at this point. Apart from this example, and the corrie basins previously cited, there remain three quite distinct types of lakes.

(*a*) Scattered over the plateau south-west of Trefriw are innumerable small lakes of very varying size and shape. These conceivably may occupy local depressions which were formed in the first instance by the solution of the limestone (already suggested as outcropping here) and have been rendered impervious by a lining of glacial drift.

Some, if not all, may equally well occupy hollows left in a mantle of drift irregularly deposited on this plateau surface. In form and mode of occurrence they are reminiscent of the drift and 'kettle' lakes associated with extensive deposits of continental rather than valley glaciers.

(*b*) Llyn Eigiau is unusual in that it lies at right angles to the general slope of the land[1]—*i.e.*, it trends roughly parallel between the two consecutive contours of 1200 and 1300 feet. It seems most probable in this case that the water is held back behind a long drift barrier which follows the eastern lake-margin. If this is the case, the lake may occupy a basin formed during early stages of the glacial retreat between the abrupt topographic slope to the west on the one hand and the supposed shrinking ice mass on the eastern side. Before final retreat the ice may have built up a dam of drift behind which waters still accumulate—hence the persistence of the lake to-day. Districts which have been subjected to very extensive regional glaciation commonly exhibit examples of this type of lake, which run along the hillside and generally are of relatively shallow depth.

(*c*) Llyn Cowlyd and the two smaller lakes at Z and Y occupy long elliptical basins in their respective U-valleys. In both cases it seems probable that the lakes have con-

[1] For a report on the depth of this and other lakes of this district see T. Jehu, "A Bathymetrical and Geological Survey of the Lakes of Snowdonia and East Carnarvonshire" (*Transactions of the Royal Society of Edinburgh*, vol. xl, 1902).

siderable depth, and occupy true rock basins, over-deepened by ice excavation. Considering the lake at Z, for example, both the lake and the whole valley which it occupies narrow in a downstream direction. This seems consistent with the surmise that more resistant rock (which would cause a lessening of the power of ice erosion) was encountered toward what is now the lake outlet, to leave the basin as one definitely over-deepened. The form of Llyn Cowlyd, together with adjacent features of relief, seems to suggest a similar origin. The lake-margin very precisely follows the line of the higher valley contours, while the complete absence of an indented margin or lake islands suggests that the abrupt slopes of the valley-side may be continued perhaps to no inconsiderable depth below the lake-level. The pointed ends of the lake contrast with the blunted front (crossing the U-valley roughly at right angles) which characterizes the 'ribbon' lake when bounded by a morainic dam rather than occupying an over-deepened rock basin. Of especial significance, too, is the configuration as shown by the contours passing immediately round the head of the lake, whose outline they repeat two hundred feet above the water-level. It is possible to develop an hypothesis in favour of (indeed, almost necessitating) the occurrence of local over-deepening in this very locality, upon the assumption that continental rather than valley glaciation prevailed here during some part of the Quaternary Ice Age. There is no lack of evidence in support of this argument.

It may be remembered that so long as valley glaciation prevails glaciers are restricted to the major lines of drainage, initiated probably in pre-glacial time. But with the advent of the local ice cap, and still more so with the continental glacier or ice-sheet, practically all relief is submerged beneath the accumulation of ice which then moves relatively freely, without restriction or close regard to normal lines of drainage, but in relation to the radiation of ice from the centre of dispersion. Thus the ice may be forced to move in an *up*-valley direction, or across divides which often become lowered, widened, or even entirely removed to form the through valley.

Through Valley. Of this latter important land-form there are at least two noteworthy examples shown on Map XIX. The water-parting between the Llugwy and Ffrancon valleys, for example, lies at X! The passage across the divide from either basin is almost imperceptible. Whether the divide has always lain exactly at this position it is impossible to say from the evidence of the map alone. It is conceivable that the Llugwy may at one time have taken its source in Llyn Ogwen, and that the Ffrancon has, by virtue of the steep gradient at the step, cut back to divert the Ogwen, together with a small part of the former Llugwy drainage, to form the present Nant Ffrancon headwaters. But even if such or similar changes have occurred, no matter where the exact water-parting may once have been, there is no ridge or divide at any point crossing between the two valleys. The first-class road may have to negotiate fairly sudden changes of gradient, but it has to surmount and cross no definite divide. A through valley may also be identified (particularly by reference to adjacent sheets) at the head of the Nant y Gwrhyd. This valley and the Glaslyn and Llanberis valleys are separated from each other by no distinct water-parting, and a first-class road quite easily forks into either valley.

But there are other features which equally support this evidence of regional glaciation. The presence of drift lakes on the plateau suggests former widespread and extensive glaciation. Ice must have covered the plateau surface for lake formation of this kind to have occurred, while the type of lake basin exemplified by Llyn Eigiau is one most common in regions of extensive regional rather than valley glaciation.

The reader will recall that the centre of ice dispersal in North Wales probably lay in the neighbourhood of Snowdon. When viewed in relation to adjacent regions it will be seen that the area under discussion lies immediately to the northeast of this centre of dispersal. If the ice radiated in all directions, then the Nant Ffrancon, Glaslyn, Llanberis, and Gwrhyd valleys would probably form natural lines along which currents could move. It seems likely also that a current would flow in some north-easterly direction, where,

however, no continuous valley is present. At the time of maximum glaciation one may assume that the ice filled the Llugwy and Gwrhyd valleys completely to their summit, so that any upper and higher currents may then have over-ridden these valleys in radiating from the centre of the ice dome. The orientation of the valley in which Llyn Cowlyd lies is exactly that which should obtain if an upper flow pushed north-eastward from the Snowdon massif. It is particularly interesting therefore, to note that there is a conspicuous absence of a divide above Llyn Cowlyd. In fact, there exists here a through valley pass, and, furthermore, there is a broad terrace cut into the eastern end of the corrie-dissected ridge at F. This terrace is only slightly higher than the pass at the head of the Cowlyd valley. It is here, too, that the Llugwy valley is considerably widened, and one wonders how far this may be due to the crossing of ice-currents (not necessarily contemporaneous) from opposite directions—*i.e.*, lower currents working within the valley from west to east or *vice versa*, and upper currents at the same place crossing the valley at right angles, from south or south-west to north-east.

Broad ice-currents, when working north-eastward, would be confronted by a divide of considerable altitude, and doubtless no small volume of ice would be constricted to flow rapidly (and therefore excavate deeply) through the lowest and most easily worn pass. Thus may have been formed the through valley breach in the divide above Llyn Cowlyd, while the ridge summits bounding the lake possibly stood out as nunataks. According to this hypothesis, one would expect to find an over-deepened basin in this very position, formed in a manner comparable to that of the glint lakes of the Scandinavian peninsula. It is important to notice that this assumed over-deepening (as recorded by the extent of the lake) occurs only where the ice will have been constricted between the high ramparts bounding the present lake. Once the ice had passed to the north-east beyond this ridge, it would fan out, and therefore exert diminished pressure—some ice doubtless continuing north-eastward down the valley toward the Conway, and some

perhaps crossing the low divide northward in front of the present Llyn Eigiau. It is difficult to explain the presence of the Cowlyd through valley, and also the presence of a lake in this position, unless the valley was fed from some more distant gathering ground. (It must always be remembered, however, that the foregoing analysis provides suggestions, and not proven facts, to illustrate the scope of the argument which students should endeavour to develop in attempting to explain the physical history of similar regions.[1])

Deposition

There is space here only to consider very briefly the identification of regions where extensive deposition rather than erosion has occurred. Many of the most characteristic land-forms are of such slight relief that it is impossible to identify them on relatively small-scale maps, where, too, the contour vertical interval is often wide. Frequently such areas are most readily identified by the exceptional prevalence of marsh and lakes of very irregular form and size, linked by a maze of indeterminate drainage channels. A region of this type is represented in Map XVIII, though the lakes in some cases are artificial. Map XVII shows one feature which can, however, be identified from the evidence of contours rather than drainage. The Tweed valley lies within a broad lowland, itself of subdued and rolling topography. The most conspicuous characteristic of the contouring is the way in which it is drawn out from south-west to north-east, while in addition innumerable closed ellipses pointing in the same direction exemplify the 'whale-back' or 'basket of eggs' topography of a boulder clay and drift-covered plain which is carved into a sequence of drumlin ridges or disconnected hillocks—all trending with their longer axis in the same direction.

Quite apart from the identification of the land-form, the contouring is interesting in rendering it possible to estimate from the map the last major direction of ice-flow near the margin of a continental glacier. Controversial though the

[1] For the map-interpretation of fjeld and fjord topography see Chapter X.

origin of the drumlin may be,[1] it is generally accepted that it is in some manner moulded by ice motion to form a 'whale-back' shaped ridge of drift, drawn out to lie parallel to the direction of ice movement. Hence slowly moving and heavily loaded ice may in this instance be assumed to have moved either from south-west to north-east or *vice versa.*

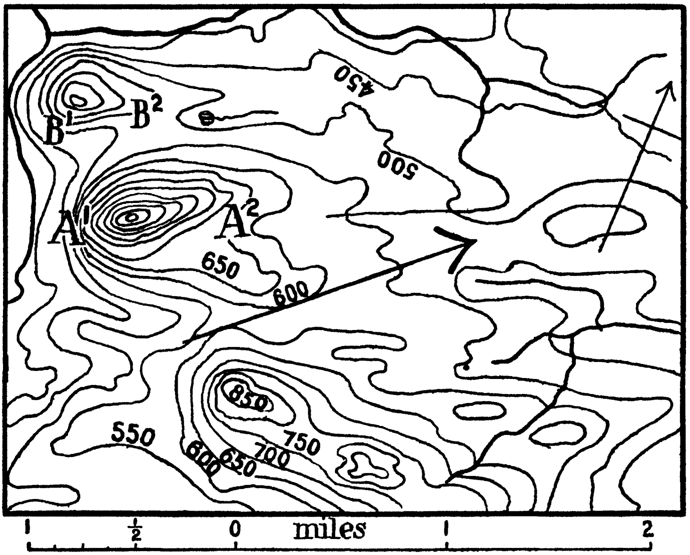


FIG. 20

From sheet 81, Ordnance Survey of Scotland.
A1, B1 = crag. A2, B2 = tail. —> = direction of ice-flow. V.I., 50 feet.
Based upon the Ordnance Survey map with the sanction of the Controller of H M. Stationery Office

It is difficult to suggest from this map alone which of these alternative directions was followed. From adjacent districts depicted on the full Ordnance Survey sheet one may, however, identify the phenomenon of 'crag and tail' (see Fig. 20). A series of contours may be traced passing closely round the western side of these abrupt hills, and forming widely spaced ellipses to the east—*i.e.*, the tail of

[1] See standard text-books on the subject, including W. B. Wright, *The Quaternary Ice Age.*

drift points toward the north-east. This shows that the movement was from south-west to north-east—an interpretation in accordance with the known gravitation of ice-currents from the southern uplands toward the North Sea.

If the more recent views of Professor Gregory are held to be correct[1]—namely, that the drumlin has been formed by post-glacial, sub-aerial denudation, primarily by wind action, and hence lies elongated in a direction parallel with local prevailing winds, which do not necessarily bear any relation to the last direction of ice-flow—then obviously the contouring loses all value as a means of identifying directions of ice motion. Gregory's views, however, have not received general support.

[1] Professor J. W. Gregory, "Scottish Drumlins" (*Transactions of the Royal Society of Edinburgh*, vol. liv, Part II (No. 8), 1926).

SECTION III

THE INTERPRETATION OF HUMAN GEOGRAPHY

INTRODUCTION

To the geographer the most important aspect of map-interpretation lies in the identification and analysis of the nature of the human response to the physical environment, for this is a province strictly his own. Nevertheless, it is essential that the full meaning and method of physical analysis as outlined in the preceding pages should be appreciated before turning to this second aspect of map-reading. The two subjects—physical and human geography—may seem to have been separated somewhat rigidly into two watertight compartments. This plan has been adopted for the benefit of the beginner, who may be quite unfamiliar with the scope of map-analysis; and since the lines of evidence and method of argument appropriate to each aspect of the subject are somewhat dissimilar, it seems best—at least at the outset—to treat each quite separately.

When, however, the student turns to read other topographical maps, without the aid of text-books, it is to be remembered that no such hard-and-fast division of the subject should occur. Inevitably the two aspects must become blended and interrelated if the correct geographical outlook is maintained, which insists on the study of settlements, occupations, means of communication, etc., *in relation to* the physical environment together with other factors.

The symbolism of especial value in the present connexion (human geography) relates to the evidence of the work of man—*e.g.*, the distribution of buildings, habitations, farms, or mineral workings, etc., and the representation of means of communication by road, railway, river, and canal. It is

necessary at the outset to remember that perfect familiarity with the different symbols which denote the varying class and state of the roads is most essential, for these provide invaluable evidence, which may be applied in a variety of ways. As in the case of the previous analysis of physical aspects, much evidence can be deduced by indirect reasoning and by the application of non-geographical facts. This is often of particular value in the tracing of causal relations.

But in addition to the analysis of the *present* occupation of the soil, the study should be amplified to trace changes in geographical values as regards distribution of population in the past compared with that of the present, changes in occupations within historic times, or changes in the value and use of highways. This aspect of map-interpretation is one which is commonly overlooked, but there is abundant material on the British 1-inch map awaiting the map-reader's investigation—*e.g.*, the marking of archæological relics or the evidence of early settlement afforded by the study of local place-names according to their derivation. It is also very important to study the village plan no less closely than the larger town plan. The analysis of *plan* in both cases may suggest geographical influences equal in importance to those deduced from an analysis of *site*.

The significance of these varied lines of evidence will be appreciated from the following chapters. It is only by probing into the geography of the past—and sometimes even of the future—that one interprets in its right perspective the nature of *present* human endeavour.

Note. In a paper entitled "A Fragment of the Geography of England" (*Geographical Journal,* vol. xv, March and April, 1900) Dr H. R. Mill includes a regional survey of the district of Map III. This the student should consult without fail (particularly in connexion with Chapter VII), as it provides much additional information which in some cases may be identified through map-interpretation, although the paper is not written especially from this standpoint. I am indebted to Dr Mill for permission to incorporate in the present work some of this material.

CHAPTER VII

SOME TYPES OF VALLEY SETTLEMENTS AND COMMUNICATIONS

In this chapter some aspects of human geography in regions of normal drainage will be studied from Maps III, VII, VIII, and XIII.

The section of sheet 92 (Ordnance Survey "Popular" edition) which is shown on Map VIII has been chosen for discussion because this area, small as it is, epitomizes contrasting physical and human relationships which as a rule are widely separated. The region will be discussed here with reference mainly to the Dove basin. Three distinct physical sections can be clearly identified: (1) the youthful valley of Farndale, (2) the limestone terrace dissected by narrow gorges below Gillamoor, (3) the open plain south of Kirkby Moorside.[1] Each physical unit has its appropriate human response.

The upper Dove valley above Gillamoor, known as Farndale, represents an isolated *cul-de-sac*, sunk into the sandstone moorland plateau on either hand, and cut off from the plain of Kirkby Moorside to the south by the limestone gorge below Gillamoor.

That Farndale is a region of only local importance is indicated by the single second-class road, which enters from the south and terminates at the village of Farndale East—the one solitary centre of this upper section of the Dove valley. Presumably this is the focus for a 'valley population,' which strictly avoids the moorlands above. A suggestion that Farn-

[1] It should, however, be remembered that the area shown on this map has been influenced, at least indirectly, by glaciation, when the glacial lake of Pickering was formed behind the North Sea ice barrier. Thus the evolution of the present drainage system has in part resulted from distinctly *ab*normal conditions. (See Chapter IV.)

dale village is probably a centre related to sheep-rearing on the surrounding moorlands rather than to cultivation is supported by the fact that there are only three farms indicated within the valley, and that all lie well to the south, toward Gillamoor. We might also suggest the possibility of local supplies of wool from the moorlands accounting for the industries associated with the mills along the upper Dove course.

In the same valley section a further characteristic of settlement in upland valleys is depicted: not only do habitations avoid the higher ground, but within the valley they show a marked preference for sites near or adjoining the lines of communication into or out of the valley. Their placement marginally on the valley-sides is associated with the lie of the roads, which do not run centrally, but drop laterally into Farndale. This apparent close association of habitations and roads, both metalled and unmetalled, reflects the general isolation of the upper Farndale basin. Above the valley-sides and over the moorland only minor, and always unfenced, roads cross the region. This latter feature indicates, as we should expect, a region of relatively small economic value—of unenclosed moorland, open and perhaps bleak—from which man to-day turns away toward the more favoured lands to the south. Whether the moorland has always similarly repelled the settler is a question which we shall answer later. For the moment we may turn to a study of settlement in the extreme south, where the physical environment is the direct antithesis of that in Farndale.

The present map gives only a very small section of the broad alluvial plain of Pickering, but, even so, this is sufficient to indicate the major features of the larger area, which can be studied by reference to the full sheet. It is here that there occur the only first-class roads in the whole region—*i.e.*, between Kirkby Moorside and Sinnington, with a branch southward (to the east of Great Edstone village). Here, too, are the only railway communications, while all settlements are linked up by a network of second-class and minor roads, unrestricted in direction by the slight undulations of the

plain. All roads, further, are fenced, which, in view of the scattered farms marked, is indicative of enclosed agricultural land.

Perhaps the most characteristic and significant feature in the plain section, however, is the way in which settlement seeks rather than avoids the highest ground. In this section of the sheet there is illustrated but one village typical of a very large number which the full sheet shows—namely, Great Edstone, which lies entirely on the circular knoll rising to a height of just over 200 feet above the general plain level, the latter here averaging 100 to 150 feet in altitude. Reference to the full sheet shows, further, how not only villages, but even individual farms all seek out the higher site provided by any minor undulations in the general level plain surface, so that the immediate flats around the irregularly meandering rivers are left almost devoid of settlement.[1] Great Edstone itself is an agricultural village, typical in form and size of many others on the Pickering plain, lying in the midst of farmlands and characteristically near, but not on, the main road, to which it is linked by second-class or minor roads.

Kirkby Moorside is the largest centre of population, and stands by the opening of a tributary valley to the plain, at the junction of upland and lowland, and at the meeting of two contrasting geographical and economic regions, the pastoral and the agricultural. In keeping with this position as a local regional centre, we might expect some small industries to develop—a suggestion confirmed by the Kirkby mills on the Dove, to the east of the village. The importance of the site from a relatively early historic period is indicated by the adjacent relics of a priory and of two separate castles. The former, symbolical of peaceful agricultural development, lies on the low river flats to the east of the village, but both of the latter, though probably dating individually from different historical periods, lie on the more commanding and abrupt slopes behind the village, and overlooking the plain.

[1] If possible the "Fully Coloured" edition should be consulted, as the hachuring renders the portrayal of minor elevations far more graphic.

VALLEY SETTLEMENTS

There remains one unit upon which we have not yet commented—a zone intermediate physically, as it is humanly, between the moorland and plain. This is the low limestone terrace, identified previously by the deep, narrow valleys of the main rivers, and by the dry valleys and broken drainage of the plateau surface, which extends over an area about 3 miles broad and 350 to 500 feet high (in contrast to the plain under 150 feet high to the south, and the dissected moorland plateau, rising to 1100 and 1200 feet, in the north).

The intermediate limestone unit comprises a region which is fairly accessible, and of some economic value, for it is crossed by second-class roads which are mainly fenced, though the small number and the distribution of settlements seem rather to indicate a value intermediate between that of the regions to north and south. It is interesting to notice how in this section the main river valleys are *avoided* as natural highways. Thus the main road from Kirkby Moorside climbs on to the limestone terrace to Gillamoor rather than follows the narrow Dove gorge, and beyond Gillamoor rises yet higher on to the moorland zone, to drop finally into Farndale. A minor road from the east side follows a similar course in avoiding the gorge of the Hutton Beck.

There are a few farms scattered over the area, which suggest a certain amount of agriculture, but the lack of surface water seems to have determined that there should be a marginal concentration of the population, seen in the series of villages Gillamoor, Hutton-le-Hole, and Lastingham. In each case the influence of water-supply in determining the location of village sites can be clearly seen, for it is at this line that the streams turn east or west along the foot of the moorland plateau from which they have descended. Thus, approximately following the 500 feet contour, and again at the junction of regions of both geographical and geological contrast—moorland and limestone—this second village line compares (but for a very different reason) with the more important line of centres bordering the northern margin of the Pickering plain (represented in this small unit by Kirkby Moorside and Sinnington).

There is only one village in this intermediate belt which does not lie at the junction of moorland and limestone—namely, Appleton-le-Moors. The orderly form of this group of detached houses, each enclosed within gardens, shows a distinctive house pattern and village lay-out. Rosedale and the Seven valley repeat many of the characteristics of the Dove basin, and a study of the Popular O.S. full 1″ sheet 92 will reveal a further repetition of many of these features over the wider region.

Within the comparatively small area included on this map we can, then, trace a variety of geographical influences, resulting in a sparse but valley-seeking population of the moorland belt, a denser, but more localized water-seeking population of the limestone belt, and a yet denser, but scattered hillock-seeking population of the agricultural plain; with a concentration to form the greatest centres of the whole region at the junction of upland and plain, and an associated parallel east-to-west trend of the main lines of communication, both road and rail.

The Mature Valley

Map VII shows the distribution of settlement typical of a river valley which has reached the stage of maturity or old age. The population again seems to be primarily agricultural, a fact indicated by the widespread farms, by the presence of mills along the river-side at frequent intervals, and on older maps by the detail of each village, which in every case consists of buildings grouped round the three fundamental features of the agricultural village community—the church, inn, and smithy. Most of the villages seem to have grown round or within either the fork of a road junction or a semi-rectangular or triangular loop of road. Villages are surprisingly large and frequent, and in almost every case there lies near by a park enclosing the "Hall." Old maps suggest that each village, possessing as it did the Hall, inn, smithy, church, and adjacent mill, recalls some at least of the characteristics of village life under the manorial *régime* in medieval England. A possible explanation,

however, of the number of obviously overgrown villages and the many large estates and country residences is suggested by an examination of the whole sheet 121, for this region is then seen to lie immediately to the north of Leicester, to which focus the district and its industries may be tributary.[1]

But apart from these considerations, the map shows one outstanding feature of greater general geographical significance (which therefore the reader will frequently identify in regions of similar form)—namely, the placement of villages on the drier sites of the valley-sides, avoiding the damp pastures of the actual flood-plain levels. Again, then, the villages tend to occur in lines, determined in this case by the meeting of water-meadow with better-drained agricultural land. Not only are the villages placed laterally, but they tend to occur in pairs, facing each other across the valley at points where to-day the river is bridged, and linked together by short cross-valley roads which are generally second-class. In this way Hoby is linked to Rotherby, Thrussington and Ratcliffe to Rearsby, Wanlip to Syston, Cossington and Ratcliffe to Rothley, etc. In keeping with a marginal distribution of population, there is a distinct marginal trend of communications, which, linking up successive villages, at the same time avoid the crossing of marsh or the frequent bridging of meander loops which a mid-valley position would necessitate. Thus it is noticeable how, particularly in the Soar valley, settlements and lines of communication tend to follow the 200 feet contour, while the site of Queniborough shows how strong is the influence of relief and the necessity for the slightly higher and drier site afforded by the valley margins. A marked contour re-entrant at this point results in the growth of the village distinctly out of alignment with the remaining lateral villages on the south side of the Wreak valley.

Human relationships of this kind can be identified on topographical maps quite frequently, but in the case of the rejuvenated valley (as illustrated in Map XIII) a different interpretation is necessary. Here the presence of spurs

[1] Note the number of *leather* mills marked as present in this region on the "Popular" map.

between the meander bends forces main roads up on to the summits above the present river flats. Consequently the two main roads of the region lie on the plateau above, and not down in the winding valley, their approximately parallel course being determined by the width of the meander belt at this upper level. (See, for example, the road from A to B and from C to D.)

Minor roads do cross the spurs and the present valley floor, as can be seen particularly in the case of the middle spur in this area, but there is neither local nor main road following continuously along the winding flat of the present flood-plain level. The presence of spurs, however, causes little deviation from the customary directness of the railway. The latter crosses the present flood-plain levels by high embankments, to tunnel through the broader and higher spurs and pass by deep cuttings through the southern spur, of lower altitude. The railway therefore occupies a position midway between the two main roads, which trend parallel to it on either side above the river valley.

The chief village sites repeat the characteristics of the roads in avoiding the entrenched valley flats. They lie in some cases on the spur summits, particularly on the slopes above the convex side of the river bends, where the gentle gradient of the spur at this point provides easy access to the plateau levels above, accessibility to which seems to be a primary factor in determining village placement. The same principle is illustrated by the fact that the station of the railway, which in its general trend follows a valley, lies almost on the summit of the middle spur, a position which is, however, within relatively easy access of either the villages or the main roads on both valley-sides.

Characteristics of Wealden Settlements

The section of the Weald shown in Map III also illustrates a farming district, with the associated village types. In studying the region one is perhaps first struck by the uneven distribution of settlements, which occur in two east-to-west belts of moderate density, separated by the broad upland

zone. The latter is conspicuous either for an almost complete absence or for a marked localization of population, and corresponds to the zone which we have previously identified as comprising part of the South Downs. In this belt scarcely a dozen farms and only six villages are indicated. The latter by their position indicate the primary cause for the thinness of settlement, for they occur either on the lowest dip slope flank—where presumably the water-table is at no great depth—or, as in the case of four, follow the only line of surface, and in part intermittent, drainage in the beheaded Lavant valley. Moreover, we may note how settlements within the tributary valley terminate at the upper limit of intermittent surface drainage, above which the very marked dry valley depression remains devoid of villages and is utilized rather for farms. In this respect it is noticeable that many of the scattered farms seem to lie at the head of dry valleys. Access to water seems, then, to be the chief factor determining settlement in this central region, and in relation to village placement is of greater importance than proximity to main lines of communication across the upland. Presumably the occupations of this population will be more closely related to sheep-farming than to the arable farming of the plains to north and south.

We should note, however, that there is one area, quite distinct from the chalk upland, which is equally if not more sparsely populated—namely, that area immediately to the north-east of the water-gap, near Amberley. Here the reverse conditions are present, for whereas on the Downland there is deficiency of water, here there is excess, resulting in an absence of population in the two regions for directly opposed reasons.

Apart from the latter area, we may consider the plains to the north and south as regions of much denser settlement, and the very marked dependency of this greater density on soil fertility, and therefore agricultural opportunities, is illustrated by the fact that whereas twelve farms occur scattered over approximately 40 square miles of Downland, in some parts of the northern plain the same number can be counted within 3 square miles. Although farms are more or less

irregularly placed, the villages have a characteristic distribution. In the plain to the north they lie in two distinct belts; the one with a larger number of smaller villages follows the foot of the escarpment, and the second, with fewer villages, but some larger centres, lies near to the Rother river itself. Between the two belts there is a conspicuous absence of villages. To the south, a third belt of villages follows the lower dip slope, east of Chichester.

Studying the form of the villages in detail, we may notice how closely the one belt hugs the escarpment base. The original Survey sheet reveals many minor third-class and winding roads skirting the foot of the escarpment and linking villages together, and also a network of *fenced* but *unmetalled* roads uniting the villages and scattered farms, a feature very typical of areas which are primarily agricultural in character. In greater detail, it is noticeable that quite a number of these villages tend to exemplify in miniature the street formation, where dwellings follow the roadside only. Particularly on the dip slope, however, the habitations of equally small villages tend to be grouped around a small sub-rectangular loop of road, similar to that identified on Map VII. Now this form is of especial interest because it exemplifies what is known as the "ring fence settlement" —*i.e.*, it may perpetuate the site of a forest clearing, dating from the time when the penetration—in this case of Andreaswald—first progressed. The road loop may indicate the early clearing in the forest around which habitations clustered. In some cases the latter have spread over the once open centre; in others this still remains as the village green or common. This evidence of village form may be used in two ways—first, as affording a glimpse into the early historic background from which the present rural life has evolved, and, second, as material of likely value in geological interpretation, since it indicates the probable *natural* vegetation of the district, whose character is now masked by widespread cultivation.[1]

[1] An impression of this phase of settlement still persisting in but partially cleared forest-land is remarkably well illustrated on some sheets of the German 1 : 100,000 map, an example being reproduced in Brunhes' *Human Geography* (1952 ed.) (Map V, p. 50).

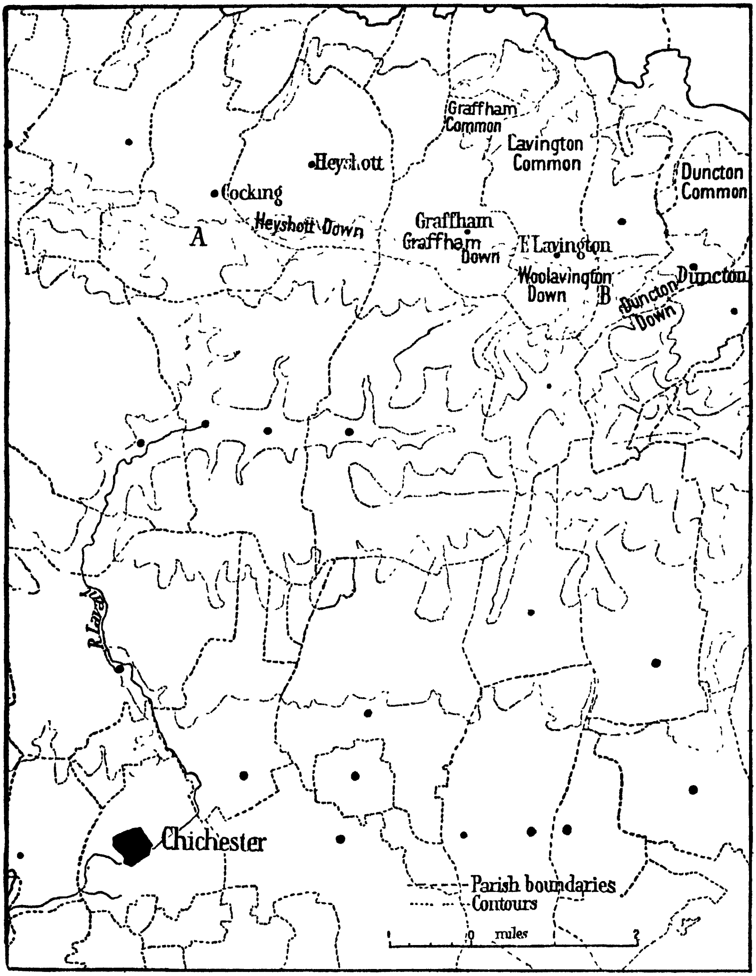


FIG. 21. DIAGRAM TO SHOW THE RELATION OF THE SIZE AND SHAPE OF PARISHES TO NATURAL FEATURES

Fig. 21 shows the parish boundaries (traced from the "Fully Coloured" sheet) for part of the western section of Map III, and is of geographical interest for two reasons.

First, we may note that the variation in the size of the parishes is related to the relief and economic value of the regions which they embrace. Thus it happens that the chalk uplands coincide with a belt of markedly large parishes and the two lowland zones with parishes of smaller size, reflecting the greater economic value and denser population of these regions. But it is furthermore significant that the southern boundary of every parish which adjoins the chalk upland does not follow the foot of the escarpment, but climbs up to include at least a fraction of the dip slope beyond the escarpment summit, indicating an overlap rather than a distinct and separate regional unity of upland and plain.

That this may be definitely related to geographical interests is suggested by the fact that parish boundaries in two cases encroach farthest to the south just where relief is most favourable for such expansion. (Note particularly the parish form at A, leading over the wind-gap break north of the Lavant, and Duncton parish, to the east, where at B a smaller lobe pushes over the escarpment summit *via* the smaller wind-gap which occurs at this point.) Most of these parishes seem to be composed of three distinct units. The first comprises a central belt of farmland surrounding the foothill village, which forms the nucleus of settlement in each parish. The second is a zone of Downland, in part thinly wooded with deciduous trees, which backs the village belt and rises at least to the escarpment summit. The third, a northern unit, is a zone of common land to which the farm belt slopes, and which is in part thickly timbered with coniferous woodland. Thus Graffham village lies amid farms beneath Graffham Down and faces northward to Graffham Common; the same feature is equally clear for the parishes of Lavington and Duncton. Alternatively we may describe these parish units as comprising segments of the parallel east-to-west outcrops of chalk, clay, and sandstones, each with its contrasting scenery and economic value.[1]

For both escarpment and dip slope village belts water-supply seems to be the final decisive factor in determining their placement. In both cases the villages seem to lie along

[1] Consult Dr Mill's paper for a further analysis of the parish form.

the spring line. On the escarpment side this lies at an average elevation of 200 feet, while on the dip slope it occurs at 50 feet. Settlement has therefore concentrated along the first line where an adequate water-supply is guaranteed, without encroaching over the apparently valuable farmlands on the one hand and within easy reach of the pastoral land on the other.

As already noted, the villages along the Rother are relatively few in number, but they include the centres of Petworth and Midhurst, which, by reason of their larger size, more central position, and—for this reason—closer contact with the main lines of communication, may function as market towns of this northern plain, the whole of which obviously is not included in this map. Unlike the villages of the spring line, they are linked together by a first-class east-to-west road, which parallels the similar main road along the lower dip slope to Chichester. Between these two east-to-west lines there exist only transverse south-west to north-east first-class roads. We realize, however, the merely local importance of both Petworth and Midhurst in contrast to the regional significance of Chichester when we compare the character of communications serving both areas. For the railway which follows the Rother valley is only a single line, presumably serving local rather than through traffic. Furthermore, Petworth is not of sufficient importance to cause a *détour* even in this local line, and hence town and railway station are separated by a considerable distance (approximately 2 miles). These characteristics of railway communications are frequently found in agricultural districts.

It is worth pausing to consider the general character of the main lines of communication in the area as a whole, for they exhibit some features of special interest. The chief route-controlling centre of the whole region is Chichester, a town whose Roman origin is clear both from its name and its plan (as this is indicated by the roads within and around the town).

Of the railways, the main north-to-south line, as one would expect, follows the Arun gap, to the south of which it meets

at right angles the east-to-west South Coast line. Chichester, in relation to the latter, is a station *en route*, and not a terminus. It is, however, a minor junction, for a secondary line—presumably for local traffic—follows the wind-gap and valley of the Lavant, corresponding in direction to the main north-to-south railway line which follows the water-gap farther east. In spite of the marked break in the escarpment where this wind-gap occurs, nearly 2 miles of tunnel are necessary to climb into the Lavant valley.

The continuity and abruptness of the escarpment slope, and the exceptionally well-developed consequent and subsequent drainage lines, has therefore resulted in a rectangle of railway lines (two sides of which are for local and two for main-line traffic), with its corners at Midhurst, Pulborough, Arundel, and Chichester.

The main roads, however, have less need to follow lines of lowest relief. Moreover, unlike the railways, roads have, since earliest historic time, grown as highways to and from the terminus Chichester (*vide* Stane Street). We may assume the perpetuation of this convergence during medieval times, when Chichester became a cathedral city (of which status we are reminded by the cathedral marked on the map near the centre of the city). It results that only in one case do road and railway routes coincide—namely, where the local railway follows the Lavant valley. This is an obvious route for a main road, both because of its direct north-to-south trend across the upland belt and because of the marked wind-gap break in the escarpment beyond, whose easy gradient at this point is reflected in the lack of bend or twist as the road crosses and drops to the plain to the north. In this respect the road contrasts with a similar one to the east, which climbs up the escarpment face and appears to ignore the control of relief as it cuts obliquely across to Chichester.

But a close study of the contouring reveals (for both this and yet a third main road to the south-east) the existence of a control similar to that which directs the course of the western Lavant valley road, for, like the latter, the two other highways across the Downs follow well-defined valleys

(in this case dry valleys), which trend toward Chichester. The central road rises up to a smaller wind-gap before dropping into the upper dry valley tributary of the Lavant valley, while the eastern road climbs the escarpment (where it rises only to 400 feet, in contrast to summit heights of 700 feet farther to the west), and thence drops toward Chichester by a dry valley, which is here known as Fairmile Bottom.

The importance of the north-to-south Lavant route—at least for a considerable local traffic—may explain the larger size of Cocking village, which lies below the wind-gap. Served by both road and local railway, it contrasts with other escarpment villages, whose position seems related to soil fertility and water-supply alone. But the consolidated form of Cocking suggests that fundamentally its growth is related to the same factors which gave rise to the whole belt of villages, for had the north-to-south highway been the primary influence we should expect the village to show much stronger evidence of growth *along* the highway, resulting in a more pronounced 'street' type of village plan.

We are led, then, to suggest that the Lavant highway is especially related to local traffic between internal foci, in spite of the apparent ease of transit across the upland by this route. Correspondingly, the form of Chichester itself leads one to a similar conclusion, for the city has grown beyond its old Roman confines not so much northward toward the Lavant route as to the east and north-east. The greater number of roads crossing or penetrating the uplands in this latter direction (including Stane Street) suggests a gravitation of the main traffic since earliest times from Chichester to an external focus beyond the north-east limits of this region.

The presence of wind-gaps and dry valleys, and the early need to focus roads on a centre well to the south-west, seem to have caused the apparent anomaly of a complete absence of any main road following so admirable and direct a highway leading to the South Coast as the Arun gap at first glance appears to be. The fact is rendered the more significant when it is noted that there is not even a continuous

minor unmetalled road following the gap, still less a third- or second-class road. Moreover, the north-to-south road from Pulborough to Arundel appears definitely to climb up the escarpment so as to follow the *upper* edge of the gap. The avoidance rather than the utilization of apparently so obvious a highway is explained when the form of the gorge is examined carefully, for, as we have already seen, the meanders of the Arun fill the valley from side to side, and the meander scars determine the width of the gap. Furthermore, the steep and half-winding walls sink to a floor which, though relatively broad, low, and flat, seems liable to extensive flood, as is indicated by a network of drainage channels and ditches. It may be tidal inundation which occurs, for the sea is but a few miles distant from Arundel. It appears, then, to be better for the road to climb on to the clear, dry slopes above the gorge than to follow either a dry but winding course along the valley-sides or a direct route over the comparatively uninhabited flood-plain, necessitating frequent bridges, as in the case of the railway.[1]

In summary, therefore, we may say that the general trend of the main railways does not coincide with that of the main roads because the railways differ from the roads in (1) the period (and to some extent the purpose) of their origin, (2) the termini on which they focus, and (3) the extent to which they are affected by surface relief.

The roadways, to which the early regional significance of Chichester would seem to have been related, converge on that centre undeterred by the gradients of the Downs. The railways, on the other hand, not only keep to the lower levels (for to them the Downs present a definite obstacle), but also, since they are a recent development, and related to external or remoter centres, pass Chichester "by the way," as a small and comparatively unimportant junction.

Finally, we may note that the relative ease of transverse road communications across the Downs, to which in part may be due the paucity of communications through the gap itself, is reflected to-day in the absence of a 'gap town' of

[1] See Dr Mill's paper for a further discussion of settlements and communications within the Arun gorge.

any size which might function as a nodal junction. Arundel, the most likely centre, is little more than a village to-day. But that this has not always been the case is seen in the presence of castles at either end of the gorge, indicating that these sites in the past have had some value as defensive strongholds. A glance at the full Ordnance Survey sheet shows that the sea is but three miles distant from Arundel as the crow flows, and one wonders therefore how far these fortress sites were holding the gap against definite sea-invaders sailing up the Arun to the Amberley flats beyond the northern end of the gorge. That the river may have been deep enough for early sailing vessels for quite a considerable distance inland is suggested by the large number of locks and stretches of canal (marked on old O.S. maps) which are found for some distance up the Rother, while below Amberley Wild Brooks no locks, but only canals (cutting across the meander loops), seem to have been necessary. Now although this canalization is presumably of relatively recent date, it does, however, suggest the possibility of the navigation of these rivers by early invaders from the sea.

But whatever may have been the exact nature of the menace, as the strategic importance of the highway declined an economic importance did not develop to replace it, and therefore neither fortress site has grown to be a gap town. Both exist to-day as relatively insignificant agricultural villages. Such at least the map seems to suggest.

The presence of many canals and locks along the Arun and Rother rivers has just been noted, and when it is realized that, in the case of the Rother, locks were so frequent that at one point three occurred in two miles of waterway it seems necessary to offer some explanation of canalization, for the region adjoins no industrialized area. This feature is surely not in keeping with a unit which is to-day so entirely agricultural in outlook. The fact that so many of the canals are marked "disused" suggests that they may represent relics of an industrial phase now passed. One is tempted to recall in this connexion the decayed Wealden iron industry, but there seems no additional evidence on this sheet which enables one to press the point. It should be noted, however,

that on adjoining sheets there can frequently be traced some further substantiation, particularly from the presence of place-names in which the words 'iron,' 'forge,' 'hammer,' etc., are embodied. For example, on the Ordnance Survey sheet which adjoins the one under discussion a tributary of the similarly canalized consequent Cuckmere river is marked "Iron river."

The story of the highways which have served this region is not even yet completed, for we have some evidence of routes utilized at more remote historical periods. An ancient —perhaps prehistoric—track following the escarpment summit may be indicated by the line of tumuli which follows the ridge, while a definite record of Roman transport is indicated by the route marked as Stane Street. The latter is of especial interest for two reasons. The first is its characteristic Roman directness—a markedly straight route, which apparently ignores the trend of relief features in its course from Chichester to Pulborough (near which lie remains of a Roman camp) and thence on to Horsham—but 10 miles distant, as the full Ordnance Survey sheet indicates. The second feature of particular interest is the decayed importance of this old highway, in spite of the fact that present main roads, like the Roman road, still cross the upland belt. Only a few miles north-east of Chichester, Stane Street becomes a second-class road, rapidly deteriorating to an unfenced track, in which form it continues to the escarpment summit. In the lowland it has become completely lost until beyond Pulborough, whence it continues again as a first-class road. This line of communication has therefore undergone a distinct change in geographical value, which can possibly be explained by a comparison with the two alternative routes crossing the upland to east and west, and thus replacing Stane Street to-day.

These climb up the escarpment, as we have already noticed, where the summit is lower than at the point where presumably Stane Street dropped to the plain; moreover, they traverse the dip slope by the well-marked dry valleys, which give an average gradient gentler than that of the more direct and more undulating Roman route. This illus-

trates the recent and present tendency to consider ease of gradient before distance or directness (see Fig. 22). In this diagram it has been assumed that the Roman road dropped over the escarpment in a direction which continued the mathematically straight line of the dip slope section of the road, and hence ran naturally along the escarpment side in the descent to the plain beyond.

The map-reader may wonder how far it is possible to trace other changes in geographical values applicable to a whole region rather than a single line of transit. It must be remembered that in suggesting facts of this kind extreme caution is necessary, for the evidence of the map alone is often of slender and doubtful value.

As already noted in the study of Map VIII, a conspicuous feature of the north part of that region is the concentration of present settlement within the upland valley, thus avoiding the moorlands. But that this distribution may not always have existed is indicated by the presence of many relics of tumulus, camp, and entrenchment, which in almost every case distinctly avoid valley and lowland. Prehistoric

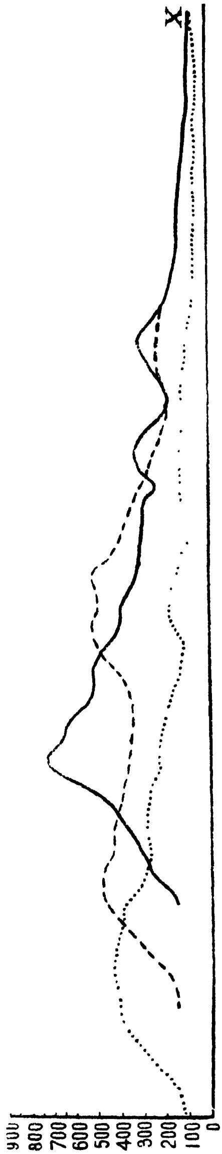


FIG. 22. COMPARISON OF ROAD PROFILES, ROMAN AND PRESENT

X lies two miles from Chichester

——— Stane Street.
- - - - Alternative branch to the north-west *via* Duncton Down.
.... Alternative branch to the south-east *via* Fairmile Bottom.

Horizontal scale, 1 inch = 1 mile.
Vertical scale (greatly exaggerated), 1 inch = 900 feet.

settlement seems to have concentrated upon just that region which to-day is avoided. The moorlands may have been but sparsely wooded or non-wooded in the past, in contrast to the Pickering plain to the south, which we may assume to have been thickly forested. The former area would therefore possess distinct geographical advantages for early man. It is interesting in passing to note how settlements, indicated by tumuli and camps, were clustered on the little stronghold site between the deep gorge of the Hutton and the Dove. That this was a zone of settlement and defence (and not simply a cemetery!) is indicated by the fact that camps and entrenchments occur side by side with tumuli. It is notable that with one exception these early historic and prehistoric relics are all found on the moorland belt, and tend to disappear almost entirely on the limestone—an unusual feature in a region where ancient settlements are so clearly indicated elsewhere. We should, however, remember that one cannot suggest that primitive settlement occurred *only* on the moorlands above the plain, for it is precisely in that one region that evidence would be preserved, while long-continued practice of agriculture in the lowlands would result in the obliteration of most traces. The absence of evidence does not necessarily imply absence of occupation.

A study of the local place-names is interesting in the light it throws on the development of agricultural settlements in later historic time. Villages such as Appleton, Spaunton, Wombleton, and Hutton) have a common termination, 'ton.' This almost invariably dates from the Anglo-Saxon period, and signifies an enclosure, or perhaps simply the site of a homestead which later became the nucleus of a village. Lastingham likewise perhaps indicates Anglo-Saxon influence in the termination 'ham' (commonly denoting house or enclosure). It is possible that the incoming Saxon influence accounts for the concentration of Celtic relics on the moorland plateau, thus exemplifying that feature characteristic of England and Wales as a whole—namely, the concentration of the invaders on the plain lands and of the original inhabitants in the less accessible and less valuable highlands.

But superimposed upon the Anglo-Saxon terms there are indications of the later Scandinavian invaders—*e.g.*, 'gill' is a common Old Norse term for a ravine, and therefore peculiarly appropriate for Gillamoor. Similarly, the 'by' termination of Kirkby Moorside is one of the safest test syllables for early Danish influences, and indicates a hamlet or village. The plain lands would seem, then, to have passed through a long phase of agricultural development under successive owners, and the clearing of the forests (which we imagine to have covered the Pickering plain, and of which traces now remain only in the relatively valueless Hutton and Dove gorges) must date in this area at least from Anglo-Saxon times. Furthermore, the place-name suggests that the geographical advantages of the site occupied by Kirkby Moorside have been utilized from an early period. The first local importance which the name indicates is that of "the village in which there is a church" (*i.e.*, Kirkby; 'Kirk' = Old English or Old Norse for church). The marking of the priory site to the east of the village supports the suggestion that this was once an important (though local) ecclesiastical centre, lying just where geographical considerations would suggest the most suitable meeting-place to be. It is not, then, in relation to present economic conditions, nor the development of present transport facilities, that Kirkby Moorside has gained its local importance.

Possibly the coming of the Normans into this region is suggested by the presence of 'le' in two place-names within this small area—viz., Hutton-le-Hole and Appleton-le-Moors. To this influence perhaps may be attributed the castles at Kirkby Moorside.

We have, then, some fragments of a long historical story in its geographical setting, dating from perhaps prehistoric times, through the long medieval period, when, in spite of chequered history, steady clearing, cultivation, and settlement must have occurred, concentrated particularly on the lower plains. The story read from the map creates that atmosphere which tends so often to elude us, wherein we see the conditions of to-day moulded upon a long and often changing evolutionary sequence, reminding us that the

present conditions are not the results of the labours of only a few generations.

The story for this small area should, however, be carried yet further, for it shows traces of the great industrial changes of the modern period. This is expressed here in the numerous old coal-pits which are indicated to the east of Rosedale, bordering the unfenced moorland road. Even these apparently unattractive and windswept moorlands have not, then, escaped the search for power which dominates the present age. Whether it has been moorland coal and wool which combined for a short period to supply the mills beside the Dove through Farndale, or whether both commodities supported the mills to the east of Kirkby Moorside, is a question which the map cannot tell. But the absence of any definite indication of industrialization to-day suggests the occurrence of what must be a purely local seam in these rocks. The abandoned pits now lie alone among the Celtic ruins, symbolical of a brief transitional phase—an economic hope of but the shortest duration.

When we turn to Map VII there are no definite indications of such early occupation, but we can again suggest the dating of many of the villages at least as clearings and centres of cultivation in Saxon times. There are here only five village sites (out of a total of twenty-one) with the Old English termination 'ton.' The termination of Rothley may, however, be derived from either the Old English 'ey' (= a water-meadow) or 'ley' (= arable land), either of which would be peculiarly appropriate to the site. Tentatively we might also suggest that the Old English 'cliffe' of Ratcliffe may be related to the meandering course of the Wreak, which, undercutting its northern bank at this point, may have determined the position of the village, above a slight meander scar—a land-form which in all probability would not be indicated with so wide a vertical interval. Far more significant than the Old English terminations is the occurrence six times of the termination 'by'; and although we do not know how far these places may replace older Anglo-Saxon settlements, at least they do suggest a strong Danish occupation of this region. This is to be expected when we recall

that this region, so near to Leicester, lies in the heart of the old Danish kingdom, and probably at an early date became a focus of Danish settlement and conquest.

One of the most interesting of the place-names is Quorndon. 'Don' may be derived from the Celtic 'dun' or the Old English 'don.' Significantly, either derivation signifies a fortified hill, which at once suggests that the obvious strategic advantages of Mountsorrel Hill were actually appreciated from an early historic period. Apart from the place-name, however, the map provides no additional evidence to substantiate this suggestion. One might be tempted to try to explain the presence of so abrupt an elevation, which is out of harmony with the gentle gradients and slopes of the surrounding districts, rising as it does, within a mile, from an altitude of 150 feet to one which exceeds 400 feet. That it is probably composed of relatively resistant rock differing markedly from that characteristic of the region[1] is suggested by the contour form of the hill, with its abrupt slopes, and also by the presence of quarries behind Mountsorrel village. This latter industry may explain the phenomenally large size and very straggling form of the village, indicating that this is not primarily an agricultural centre. If we are familiar with the famous pink granite building stone named Mountsorrel granite, then the place-name would suggest an explanation for both hill and quarries, but, apart from this knowledge, we can give no definite explanation from the map. (Actually, the hill represents an isolated, exposed relic of the old igneous rock mass which forms the Charnwood Forest uplands, rising from the plain but a few miles to the west of the region.)

Finally, it is equally possible to trace from Map III changes which are similar in many respects to those identified in Map VIII, though repeated in this case over a much larger area. The moorland and limestone terrace (Map VIII) are here paralleled by a much larger upland area of chalk Downland, which in a similar way is scattered with relics of

[1] The presence of outcrops of Triassic sandstone, accounting for the softer profiles of the region as a whole, is suggested by the marking of *gypsum* mills (see "Popular" map).

tumulus, camp, and entrenchment, indicative of a prehistoric or early historic importance in a region now but thinly peopled. We may even visualize Neolithic man settled relatively densely on the dry, healthy uplands, which were but thinly wooded and comparatively easily cleared. Here he has left most traces, particularly along the escarpment summits —now treeless. If this line of tumuli marks the zone of densest settlement, then it is an interesting prehistoric counterpart of the present line of foothill villages a few miles to the north. If, however, it traces out a great highway of Neolithic man, it parallels the east-to-west lines of road and railway communications, which follow either the Rother valley or the lower dip slope flanks.

But whether the relics represent either the trend of a prehistoric highway or a series of isolated settlements, we can visualize the outlook of these early peoples from so commanding a position, which gave freedom from dense forest or marsh, and, above all, 'foundries' of flint stones, yet overlooked woodland and swamp in the Wealden forest to the north, with a horizon frequently that of the open sea to the south.

But the coming of the Romans heralds the change in geographical values that is to follow in later history, for Stane Street cuts across chalk upland and clay vale alike, and relics of camp and Roman entrenchment are found equally on the Weald plain and on the Downs.

The "ring fence settlements" (in many cases possessing place-names of Saxon origin) afford a glimpse of the transition, when scattered groups of nucleated settlements broke the continuity of elsewhere thickly wooded lands.

Finally, man's persistent struggle with nature has resulted in a complete reversal of former values, for the lower vales, now cleared and drained, have become the zone of densest settlement. Uplands of almost unbroken solitude overlook farmland, woodland, or park. The Downland appears to-day as a region which, although it divides, does not isolate. Yet at the same time it stands aloof from the present tide of human development, with the exception of such curious associations as that which occurs to the north-east of

Chichester. Here the camp and entrenchments from which the alarmed Britons may actually have scanned the horizon as the Roman triremes approached the Channel shore to-day look down on the Grand Stand of the Goodwood race-course![1] This evidence of the changing value of the Down-land is no less characteristic than it is striking.

Note. Students who are interested in the study of place-names and the possibilities of their uses and application in other studies should consult the series of volumes for individual counties published by the English Place-name Society, and particularly vol. i (Part I, "Introduction to the Survey of English Place-names," and Part II, "The Chief Elements used in English Place-names").

In map-interpretation this type of evidence must be used with extreme caution. The subject is a difficult one, and hasty deduction is very often inaccurate.

Any interpretation of Scottish Ordnance Survey maps is considerably aided—at least, for English students—by reference to the very useful "Glossary of the Most Common Gaelic Words used on the Ordnance Survey Maps," which is published by the Ordnance Survey Office.

[1] According to archæological investigations this camp site is one of high antiquity.

CHAPTER VIII

METHOD OF TOWN-SITE ANALYSIS[1]

In no case have maps previously considered included a town of any considerable size, but nevertheless town-site analysis is an exceedingly important part of the map-reader's task. The beginner must beware of merely selecting from the store of geographical labels one appropriate to a given town site. For example, a centre which the map clearly shows to be a focus to which routes converge from all directions may not simply be described as a "nodal junction," the analysis following, and concluding, with but an enumeration of the actual converging routes. It is necessary to probe more deeply, attempting not simply to describe the town in relation to its regional setting as seen to-day, but rather to develop a picture of its growth as an organic unit since its first inception, tracing the perpetuation or decline—as the case may be—of any purely local advantages or disadvantages in relation to historical and economic changes. We must, in short, distinguish between site and situation—the former related to immediate position and environs, the latter to regional associations. The degree to which such an analysis may be carried naturally varies with different examples, and the map may provide tantalizingly inadequate evidence, but at least we may illustrate the scope of this exercise from Map V, which shows the position of Carlisle.

Apart from regional associations, there are certain obvious geographical influences which have determined the site of the city. In the first place, Carlisle has grown over the low divide between the Caldew and Petteril confluences, to be bounded roughly on three sides by a river-frontage, though there is now evidence of suburban growth westward beyond these limits. What centre, however, within this area is the

[1] See Appendix, p. 299, for further facts regarding the site of Carlisle.

real nucleus round which the city has grown? Historical associations typified by the Roman Wall and the *vallum* no less than the site of the medieval castle point to the north-west corner, within the angle of the Caldew and Eden river confluence, as the nucleus from which city development has spread both southward and laterally. The map suggests some possible physical reasons for development in this direction.

The section of the Eden valley within which Carlisle lies has clearly reached the stage of maturity, for a relatively broad flood-plain is bordered by gently sloping valley-sides, except where decided meander scars occur—namely, to the west of the Eden and Caldew confluence, where the river cuts first against the north and then against the south valley-side, immediately beyond the city. It seems probable, too, that river action has steepened the spur slope at Stanwix (R.F.) where the river is certainly undercutting part of its northern bank. Unfortunately, on the 1-inch map contours are not continued through urban districts, but a study of bench marks and spot heights on the 6-inch and larger-scale maps gives clear evidence of a sharp rise in altitude at the castle site itself, a position which seems to represent the northern end of the low inter-valley spur. From an altitude of 83 feet at the castle ramparts the ground drops abruptly to heights of less than 50 feet on the flood-plain below. It is not possible to read from the map alone how far the low scarp on which the castle stands has been steepened by river action as a bounding wall of the Eden valley, but the present direction of the river meanders supports a surmise that this may at some time have been the case. The very presence of a castle (at C, Map V) suggests the existence of some abrupt, if low, elevation, for whereas a rising valley-side and possibly a low meander scar summit would prove an attractive position of natural defence, conversely, if these are absent here, it seems unlikely that the castle would have been built on a flat, probably waterlogged plain, especially when there are many more suitable alternative hill-sites bordering the river near by. It is interesting to notice in this connexion how the castle at Arundel (Map III) utilizes the same natural feature which we surmise to be present below Carlisle Castle,

for Arundel Castle is placed above the meander scar cut by the Arun in a last westward bend before leaving the water-gap for the open plain to the south. (*Vide* also Wareham Castle, Fig. 29, Chapter XI.)

Here, then, is a site where steepened spur slopes face each other in just that section of the valley where the flood-plain is relatively narrow. The southern spur provides a site which is not only dry—since it is above the risk of flood or marsh—but also is capable of easy fortification, yet at the same time is placed where a minimum of bridge and causeway is necessary to effect a valley crossing.

In addition, the full Ordnance Survey sheet shows that the region is quite close to the Eden estuary, indicating the further value of a site here which could be reached from the sea—if not at the present time, at least by former boats of quite shallow draught.

It is impossible to deduce from map-reading alone when first the position was utilized or was of any importance,[1] but the map gives clear evidence at least of Roman occupation and interest, in portraying both Hadrian's Wall and the *vallum* as crossing the Eden valley here. To the east of Carlisle these both lie on the northern side of the river, and trend abruptly to the north-east beyond Stanwix (beside R.F.) to follow the Tyne gap. The place where the Wall presumably crossed the Eden is shown by a line marked on the 6-inch map (Cumberland, sheet 23, N.E.). This is drawn obliquely from the spur at Stanwix south-westward across the valley to follow subsequently the *southern* margin of the valley above the meandering river-course.[2]

If in imagination we entirely remove from the map the town of to-day, and think only of the site, then the Carlisle of Roman times appears vividly as a far-flung outpost of the great empire, a frontier station immediately behind this remotest line of defence, in contrast to its *rôle* to-day as a centre of gravitation for regions both to north and south.

[1] Though Carlisle may have a far older foundation, it is not possible from the point of view of map-interpretation to deduce any facts relating to pre-Roman times. See Appendix, p. 299.

[2] But the general Roman crossing-place may have been by a paved *trajectus* farther to the east, due south of Stanwix. See Appendix, p. 300.

There is still evidence of much indeterminate drainage over the region as a whole, while on the Eden flood-plain the absence of settlement (either urban or rural) points to considerable risk of inundation. This corner of Roman Britain may, then, have comprised a region of extensive marsh and forest. Under such circumstances the supreme importance of a dry site and bridge position (if the wall of defence was to follow the Tyne gap) must have meant that this area was worthy of strong defence, particularly when it is seen in addition how admirably protected a quadrilateral of land lay to the south of the Eden, enclosed on three sides by a water-front (determined by the confluence of the Caldew and Petteril rivers with the Eden).

It is not surprising, therefore, to find that north of Carlisle (which, as the student of history may recall, was known as Luguvallium) there lay a Roman fort (R.F.), holding the northern approach to the river-crossing. On the "Fully Coloured" edition (unlike the "Popular" edition) this Roman fort is definitely named Axeldon, and hence must have been an additional defence to Luguvallium, which lay, presumably, to the south of the river. The choice of the site of Axeldon (now replaced only by the former village of Stanwix) is clearly related to the ease of defence at this position. The fort lies on the spur already described, with its steep drop to a river meander loop which encloses the spur on almost all sides. Only to the north-east was the fort exposed, and here, to complete the circuit of defence, lay the Wall. But in relation to commercial rather than strategic needs the site of the fort is relatively restricted, and it may be in part at least due to this factor that Roman Carlisle (and still more so, modern Carlisle) has not expanded northward across the Eden in this direction.

As we pass on to study the fortunes of the city in succeeding eras, the unchanged *rôle* which the city has played since its earliest traditions becomes a significant fact. For though the web of route convergences was far from complete in relatively remote Roman times, yet it was the meeting of two routes—even to-day of greatest importance in the completed network—which made Luguvallium so important a

Roman centre—*i.e.*, the cross routes of the Tyne gap road and Great North Road of Western England. To-day the main first-class road following the plain of the Eden to the south for a considerable distance perpetuates the old Roman road, which therefore, in spite of the development of many subsidiary routes, remains unchanged in importance. (See Map V, and compare Stane Street on Map III in this respect.)

That the site did not fade into insignificance in medieval times is indicated by the presence of the castle, marked on some O.S. maps in Old English lettering, indicating probably a pre-Norman origin. The geographical interest of the position of the castle has already been noted. The whole city has grown southward from this nucleus, confined almost entirely within the river-bounded quadrilateral of land. We may visualize the castle as having been built as a defence against inroads from the north—reminiscent in this respect of the constant menace of Border warfare. Had the castle been built on the site of the older Roman fort at Axeldon, it would have lain most open to attack on the north side, from which direction the danger came. The Wall, though an adequate, if artificial, defence when patrolled by Romans against barbarians, would scarcely be a sufficient protection for the relatively equally matched combatants of later history. The site chosen for the castle has just those advantages which Axeldon lacked, for it has a broad water-frontage provided by the Eden river, possibly augmented by a zone of marsh on the flood-plain—a fact suggested by the present use of the plain as a public park rather than for urban expansion. Even for this use, heavy embankment has obviously been necessary.

Immediately to the west of the castle grounds the Caldew bifurcates to enter the Eden by two distinct distributaries, which appear to cross a section of flood-plain—perhaps liable to inundation. Though the course may at least in part be artificial, the main distributary passes near to the castle site, and would appear to be an admirable southward continuation of the natural south-east to north-west outer moat which the Eden river itself provides.

At a position, therefore, where the river could be crossed,

yet where defence was relatively easy, Carlisle originated as a route focus in a region which we know to have been subject to Border conflict through a long historical period. From some such nucleus Carlisle has grown primarily southward within the triple river boundary, ultimately to attain its present size.

The broader *regional* importance as distinct from this purely local attraction can be gauged only from a study of the full and adjacent Ordnance Survey sheets. On this section of the map we can, however, distinguish the terminal ends of the main routes, although their entire direction cannot be followed. Thus A is part of the main north-to-south highway from beyond the Scottish Border; B the road from Newcastle, *via* the Tyne gap; C a road of lesser importance, leading from Cockermouth and the Lake District to the south-west; and D the Great North Road of the west (still on the site of the Roman road), leading from Penrith to the south. These roads, like the railways, focus on the heart of the city, together with a network of minor roads and a single-track railway.

The character of the communications clearly indicates the dual importance of the site. When viewed from the west they portray Carlisle as a market centre for local produce. On this side predominantly minor roads radiate from the city, while in addition it is here that there trends the only single-track railway, indicative not only of the local character of the traffic which this line serves, but further emphasizing the absence of any external remoter regional centre providing any through traffic from this western direction.

On the eastern side of the city a contrasting scene is presented by the many double-line railways and first-class roads which converge toward the city to remind one of Carlisle's greater regional significance as an age-long and exceedingly important route focus.

Therefore a sequence of historical changes has been associated here with a perpetuation or perhaps an increase (rather than a decline) in the importance of the local and regional values. Carlisle still stands to-day as the focus where main lines of traffic may cross the Eden river, though in every

case the railways and present roads cross the river at a position slightly to the east or west of that followed by the old Wall. The latter, a strategic necessity of bygone times, is to-day a monument of historic interest only; yet lines of commerce, both by road and rail, focus on to the city from the same great highway, the Tyne gap, in places (as the adjacent Ordnance Survey sheets show) coinciding closely with the route followed by Hadrian's far older line of defence.

The more recent *rôle* of the city as a collecting centre of regional significance—an economic rather than a military focus and junction—is symbolized on the map by the innumerable goods-yards, sidings, and link railway-lines indicated within and around the city, a striking contrast to the old castle and still older Roman remains which lie so closely adjacent.

It is scarcely necessary to point out how contrasting may be the analysis of other town sites. We have already cited cases where towns of assumed early significance have declined in value, and have yet to discuss further examples (*e.g.*, in Chapter XI). Conversely, particularly in industrial England, sites clearly of only modern development, based on no continuous growth through a long historic period (as traced in the case of Carlisle), may be identified; for this, therefore, the student should be equally watchful.

CHAPTER IX

HUMAN GEOGRAPHY IN GLACIATED REGIONS

It has been said that "the topographical map is the most exact and faithful expression in all its details of the distribution of population." But from the point of view of map-reading (and especially in the interpretation of maps of glaciated Alpine regions) this statement is in need of some modification, for it should be remembered that evidence of settlement is gauged primarily from a study of habitations. In the case of Maps XIV, XV, and XVI habitations are indicated by dots, which, however, simply indicate some form of shelter, with no distinction as to whether it is of use for seasonal or permanent occupation, or whether it is a shelter for man or for his beasts! Here is a case, then, when the information which the map alone suggests might lead to an entirely false estimate of both numbers and distribution of settlements, for although by their frequency the dots indicate the relative importance of various parts of a region, and afford testimony as to places where, for at least some part of the year, a population of varying numbers may be found, they can form the basis of no accurate numerical estimate. In such regions the home unit is a homestead of several buildings rather than a single dwelling.[1]

Furthermore, when we remember that several habitations at varying altitudes may be used by only one or two individuals in the course of a year, obviously it is more than probable that the dots give a very exaggerated picture of the total number of families. The following table should be studied carefully, for it indicates clearly the danger of attaching any great value to actual numerical estimates of the population based upon this line of evidence. The dots counted from the

[1] Brunhes, *Human Geography*.

Comparison of Map Estimates of Population and Actual Census Returns

Commune	Number of Habitations indicated on Map				Actual Census Returns (by Communes), December 1, 1920			—
	1	2	3	4	5	6	7	8
	Grouped habitations—i.e. included within the village nucleus	Scattered habitations: On north-west valley-side	Scattered habitations: On south-east valley-side	Total number of habitations per commune (both sides)	Number of houses in occupation on December 1, 1920	Number of families per commune	Total population per commune	Percentage of total number of habitations marked on map occupied on December 1, 1920
Obergesteln	60	64	2	126	33	44	204	27 per cent.
Ulrichen	55–60	34	35–40	120–130	29	46	211	28 per cent.
Geschinen	65–70	25	45	135	17	22	88	13 per cent.
Münster	160	64	50–	270	72	102	465	27 per cent.
Totals	340 (approx.)	180 (approx.)	130 (approx.)	650 (approx.)	151	214	968	

Total north-west side 520

Total scattered 310

map and recorded in columns 1–4 are taken from an area slightly larger than that shown in Map XIV, so as to include full commune estimates. Columns 4, 5, and 8 particularly should be compared.

Although the map estimates of habitations vary for different communes (*e.g.*, Münster, 270, and Obergesteln, 120–130), yet, except in the case of the commune of Geschinen, where there are more habitations (135) marked on the map than there are inhabitants (88), according to the census, there were in all communes only 27–28 per cent. of the marked habitations actually occupied on December 1, 1920 (*i.e.*, the date of the census returns). We should, of course, remember that the census was taken at that time of the year when the population would tend to be most consolidated—presumably in the villages. But even when we calculate the percentage of village habitations that would actually be occupied (assuming the entire population to be segregated within these centres on December 1), this calculation (from columns 1 and 5) again shows an excess of habitations over the apparent needs of the inhabitants, for only 55 per cent., 53 per cent., 26 per cent., and 48 per cent. of village habitations would in this case be occupied in each village respectively. The great value of this table is to give a measure of the accuracy of this type of evidence which could be applied generally for similar regions.

But though it should always be remembered that the dots do not necessarily represent *occupied* habitations, whatever the season of the year, yet at the same time they are of the greatest value to the map-reader in determining the geographical influences underlying the general distribution and character of settlement. In this respect we may establish from the evidence of Map XIV three fundamental influences: altitude, aspect, and accessibility (as determined by slope or gradient).

The first obvious characteristic is the concentration of settlement within the valley. It is here that the only villages occur, while almost all scattered dwellings outside the villages are placed on the lower valley flanks. At least two-thirds of the dots are placed below the 1600 metre contour. But

it is equally important to notice that the population does not gravitate to the lowest levels. There is apparently a lower as well as an upper limit to settlement, for the lowest valley flats are avoided as much as the greatest heights, resulting in as little evidence of settlement below about 1350 metres as above 2400 metres. The habitations are therefore most densely distributed as two ribbons flanking the valley-side between 1300 metres and 1650 metres, and densest of all at approximately 1400 metres. Of the two ribbons, that on the right-hand side is denser than that on the left, and is knotted to form the four centres of Obergesteln, Ulrichen, Geschinen, and Münster.

An explanation of the marginal rather than mid-valley position of settlements seems clear when we read the map evidence of extensive marshland bordering the Rhone river, a factor repelling settlement from the lowest flats in the immediate vicinity of the river. On the contrary, there occur on the valley flanks the series of alluvial fans whose form has been described previously. These, it may be assumed, provide valuable opportunities for irrigation and cultivation, combined with the advantages of a relatively dry site, and, furthermore, a position on a slope that is gentle, and yet probably sufficient to rise above the levels where winter inversions of temperature may bring risks of intense cold and fogs.

Thus we may visualize a population which is concentrated in a marginal zone of cultivation, facing a flat but partially waterlogged valley floor (suggesting rather a zone of rich pastoral meadow-lands), and backed by a steep, and in part forested, valley wall. In keeping with a marginal distribution of settlement, communications (except in the case of the railway) trend along the foot of each valley wall. Particularly is this the case along the right-hand side (*i.e.*, the north-west side), and it is interesting to notice how the one road of the whole region repeats the contour bends of the alluvial fans from village to village.

Ignoring for the moment the chances that many habitations may represent dwellings of but seasonal occupation, we might suggest at first glance that the two belts should

enjoy a relatively distinct and separate existence, with but little intercommunication between the two sides, for there are few bridges or transriverine link roads. This therefore would suggest a longitudinal rather than *transverse* valley unity and interest. But that the reverse may be true is suggested by other lines of evidence—*e.g.*, that afforded by the trend of commune boundaries. As in the case of the parish boundaries of the Wealden foothills (see Chapter VII), these may demarcate local spheres within which there is, or has been, some measure of economic and social unity, based upon fundamental geographical considerations.

Though local movements and interests of the population may not be restricted to the commune limitations, the form of the latter is at least suggestive. There are four communes indicated on this map, and in every case we may view each one as a complete transverse section of the valley, passing from the highest alp to the valley bottom and across to the highest alp of the opposing side. This same feature is equally characteristic of the area shown in Map XV; indeed, in a study of a large number of Swiss sheets depicting areas widely separated this transverse commune form will be found to be of fairly common occurrence, more especially in the secluded and relatively narrow valleys, and particularly if these trend in a similar direction—*i.e.*, approximately from north-east to south-west.

In detail it may be noted how frequently the boundaries follow either the water-parting between adjacent tributary mountain torrents or, alternatively, a forested ravine. The use of the latter is especially common just where we should expect most to find it—namely, where boundary delimitation is most difficult—*e.g.*, down the forested slope of the south-eastern valley wall.

Within each commune there is but one distinct focus of settlement—in every case one of the four villages present in this little region. We can visualize the gravitation of the population within each commune toward these centres with the approach of winter, and the corresponding exodus—particularly of herders—spreading steadily from the village nucleus even to the highest alp on either valley-side with the

rising snow-line of the spring and summer months. The picture becomes yet clearer when we follow the trend of the mule-tracks and footpaths, which ramify from each centre not only up the wall *behind* each village, but in some cases also across the valley, to climb even to the highest alp of the opposing flank—a goal at which tracks terminate abruptly. This is particularly clear for paths from Münster, Obergesteln, and Geschinen.

The evidence of these footpaths is particularly valuable, for in a region of this kind not only would there exist the minimum number of tracks and footpaths consistent with the needs of the villages, but they should definitely represent the trend of movement, from which, owing to the topography, there would not be material divergence.

The paths indicated are of two kinds (see General Key), the mule track representing the routes most frequently used. On the transriverine[1] side there are only a few mule-tracks indicated. One leads through the belt of habitations as far as the Münster commune frontier, and therefore parallels the made road which links the villages together. Two other mule-tracks (leading from Obergesteln and Münster respectively) follow the only two tributary valleys entering from this side—namely, the Eginenthal and Merezenbach. Perhaps herein (at least in part) lies the secret of the large size of Münster. It is the only centre having access within its own boundaries to two tributary valleys, one on either side of the Rhone, in both of which the small groups of habitations suggest a value in pasturage if not actual cultivation. Part of a fourth mule-track is indicated, rising from the village of Reckingen (lying just beyond the limits of the area shown here, but occupying a position analogous to that of the other village sites) to an alp at 2100 metres, near the Münster boundary.

In addition to the mule-tracks, there are the footpaths which lead up either valley-side to the upper alps, situated above the shoulder of the valley wall. These upper pastures seem in general to be used by, or perhaps belong to, the

[1] For convenience we will refer to the two valley-sides as the village and transriverine sides.

members of one commune only. Thus the alp above each village takes its name from the focus below (*e.g.*, Münstergalen, Geschinergalen, etc.). Further, we may note that on the village side only in one instance do tracks from two different communes converge to one alp—namely, at Münstergalen, at 2100 metres, which is approached by paths from both Münster and Geschinen.

The character of seasonal movement in the Alpine valley is so varied, and often so complex, that it is impossible to lay down any fundamental rule for determining the extent to which it occurs simply from map-reading, but at least an approximate value may be obtained by noting the general distribution of habitations and their relation or proximity to villages and churches. The latter are of extreme value in the isolated valleys, where truly Alpine life remains still but little modified.

All who have come into contact with the real and but little 'modernized' peasant life of the isolated Alpine valley will readily recall the frequent and often considerable gatherings focusing round the church as the centre of thought in the main villages. Or, more remote, one remembers the relatively isolated chapels at higher altitudes, used during the summer season. Here, as by chance one passes in the mid-weekday morning, the congregation (consisting perhaps of a mere handful of simply clad, humble peasant men, women, and children) may emerge from the short service to take up again their load of carefully packed hay, or reshoulder baskets and cans of butter and cheeses, or untether the few cows—all left together outside—and so pass on their way after the brief halt, to become quickly lost to sight, dispersed along the several bifurcating paths leading to and from this little focus and landmark, with its whitened outer walls and crudely painted interior. We cannot escape this permeation by religion of the daily lives of these people, and thus the more readily appreciate the significance of the symbol denoting either church or chapel on the topographical map.

It is possible to suggest, though but tentatively, that if there is no church indicated among isolated groups of

scattered habitations, this may signify that these are used only for very temporary occupation—for example, by the few herders who accompany the village flocks to the high pastures.

Where, on the other hand, church or chapel nestles amid the consolidated village group we may visualize this centre to be the real focus of the whole population, where almost all will congregate at least during the winter months.

In the summer the village numbers may be markedly depleted, the degree of depletion depending on the amount of seasonal movement of cultivators, which takes place in addition to the simple movement of herders.

When on the map we can identify a transition from the village zone up the hillside into an area of few paths, few habitations or shelters, and no chapel or church, we may assume that there occurs the type of movement described as 'big mountain'[1]—*i.e.*, a seasonal movement of a few herders only, with a large number of cattle per herder. It is common knowledge that the herder pauses in his migration at temporary halting-places, which we may identify on the map by the small, compact groups of habitations marked at intermediate heights near or along the footpaths. The most important of these halts is that of the *mayen*, used during the spring and autumn transitions, and since it is used by a few herders alone it tends never to possess a church. Thus the identification of this form of settlement is relatively easy—a fact of great significance, for the presence or absence of the *mayen* gives some indication of the extent of cultivation in the submontane zone between village and upper alp levels. When, therefore, a church is marked at what otherwise appears to be a *mayen* halt it rather suggests that a longer sojourn occurs in this vicinity than simple pastoralism would necessitate. In addition, we may sometimes find habitations widely, yet relatively densely, scattered beyond the village zone, and associated with church or chapel likewise remote from the villages, and occurring at quite considerable altitudes. Paths from the village centre, and

[1] *Grand montagne*. See P. Arbos, "The Geography of Pastoral Life," in the *Geographical Review*, 1923, vol. xiii, p. 567 *et seq.*

between scattered habitations and isolated upper churches, ramify both along as well as up the valley-side. In this case there may be a relatively prolonged exodus of a large proportion of the population into the submontane zone for the 'little mountain' type of seasonal migration, where many herders each tend a few cattle, the movement thus including a large proportion of the village population, primarily to extend the zone of agriculture high up the valley-sides.

Now applying these general considerations to Maps XIV and XV, we may argue that Map XIV probably depicts a region where the 'big mountain' type of movement occurs. Already it has been noted how the paths lead up to the high alps. But by the way they pass through zones almost devoid of habitations, while what may be the true *mayen*, churchless halt is indicated in the groups of shelters marked above Obergesteln at 1500, 1600, 1800, and 1900 metres. On the whole, there is a conspicuous absence of evidence of cultivation above the alluvial fan slopes.

It seems more feasible to suggest that, while a few herders are moving between higher altitudes, the bulk of the population remains near the valley floor, extending cultivation over the lower cone flanks and seasonally migrating to the transriverine side of the valley, in which latter direction rather than by vertical movement the expansion for agriculture takes place.

In support of this suggestion we may note how on the transriverine side villages are entirely replaced by scattered habitations, but at the same time the presence of two chapels suggests some fixed, though temporary, settlement within this zone. One chapel lies on the Eginen fan, the other near the Ulrichen commune boundary; thus both occur within that section of the valley which lacks both bridges and transriverine link roads to the village centres. Significantly, too, within the Münster commune boundary there is no transriverine chapel present—*i.e.*, just where a bridge and mule-tracks are marked linking the two valley-sides directly. If the above surmises are correct, it is easy to suggest why this type of seasonal movement should characterize this valley; the map supplies evidence of very abrupt

walls backing the belt of strongly developed alluvial fans, and thus the attraction of vertical movement is minimized.

Within the area shown on Map XV the seasonal movements are probably of rather a different character. It should first be noted how in this case again the transverse valley unity is illustrated: (1) by the trend of the commune boundaries, here clearly crossing the valley from side to side; (2) by the ramification of paths from each village up to the alp on either side, the greater number naturally occurring on the village side of the valley; (3) by the naming of the alp above the forested slopes of the south-east side[1] according to the name of the village within whose commune boundary it lies, and which it faces across the valley.

But of greater interest in determining the character of seasonal movements is the fact that a zone of relatively thickly scattered habitations rises up to Alpine heights, and, further (as in the case of the higher slopes above Kippel), that a church is marked quite remote from any village centre, occurring at an altitude of 1900 metres. In addition, the map suggests evidence of a type of movement which characterizes many valleys—namely, the movement of a large proportion of a village population seasonally to a second village centre at a higher altitude. The latter, which they may 'own,' is named after the winter 'headquarters.' Thus between Blatten and Wiler there lies a village named Ried, above which lie two distinct little groups of habitations, forming an associated group of settlements, from about 1500 to 1700 metres, which are named as Ried, Oberried, and Weissenried. From the map alone it might be inferred that these mark stages in the vertical movement of the population from a winter primary centre at Ried itself. Although there is a vertical movement of a considerable number, and not simply of herders alone, in the valley as a whole, actually here there is a reversal of the normal upward summer movement to some extent. For Weissenried is not a temporary

[1] See original Swiss map.

settlement, but the highest permanent settlement in the whole valley, and in winter occupies a position more favourable than that of the lower centres at Ried and Oberried—sites which are then hardly used. The reasons for this are demonstrated by reference to other methods of map analysis.[1] (See Appendix II, p. 302.)

As a whole, however, the area depicted in Map XV to some extent exemplifies the 'little mountain' type of movement, involving a much greater depopulation of the lower valley during the summer season than would be the case in the valley shown in Map XIV. The contrast in the type of movement in the Lonza as compared with the Rhone valley may be due to two factors, both again suggested by the map.

(1) The relatively gentle gradient of the valley wall in the former region (see especially the wider spacing of the contours between 1800 and 2100 metres) might encourage a greater range of cultivation than was possible in the Rhone valley (Map XIV), although the actual altitudes of the two regions are similar.

(2) A second influence comes from the regional relations of the districts, which cannot be appreciated fully without reference to the entire sheets Visperthal and Grimsel. The upper Lonza area, unlike that of the upper Rhone (Map XIV), is almost a complete valley 'island' walled in on every hand, and sunk between extensive ice- and snowfields at the head and side of the valley.[2] Below Kippel the river itself provides an almost equally effective barrier in the stupendous gorge which it has cut to the Rhone valley level, and whose upper limit is indicated at Kippel by the shading on either side of the river, indicating the first traces of incision.

The greater isolation of this area as compared with that shown on Map XIV may be measured humanly by the fact that whereas the latter region is served by one road and also

[1] Weissenried (1694 m.) at present comprises a hamlet of ten families. For some general geographical information regarding the Lötschenthal see "The Lötschenthal: a Regional Study," by J. F. Unstead, in the *Geographical Journal*, April 1932. See also the Appendix to this book, pp. 302–304.

[2] Note the ends of glaciers marked on either side of the valley.

a railway,[1] the Lonza valley can boast neither, and is served only by a mule-track linking together the relatively small villages of the valley floor. Thus the second factor contributing to the marked extension of the submontane zone of cultivation may be this very isolation, resulting in the need for the valley to be in large measure self-supporting, and in this way encouraging the extension of agriculture to its extreme limits.

There is one fundamental geographical influence, not yet considered, which ultimately seems to have determined the distribution of habitations within the valleys depicted in both Maps XIV and XV.

The estimate of numbers of habitations given in the table on page 160 shows that there are altogether 650 habitations marked on Map XIV, and significantly these are almost equally divided between a scattered and a village position —310 scattered and 340 village. What is of greater importance, however, is the fact that not only do all the villages lie on the one side of the valley, but, in addition, a greater number of scattered habitations lie on the village side as compared with the transriverine.

Counting the distribution by altitude rather than by commune limits, we arrive at the following estimates:

Altitude	*Village Side*	*Transriverine Side*
(1) Below 1800 metres	160 + (scattered)	110 (scattered)
	340 (village)	— (village)
	500 (approx.)	110 (approx.)
(2) Above 1800 metres	20 +	20 +
	Total 520	Total 130

The above figures suggest a distinct contrast in the value of the valley-sides. The concentration of the habitations on the lower flanks of the village side would at first glance seem to be related primarily to the presence of the marked belt of alluvial fans. Thus the more scanty belt of habitations on the transriverine side coincides with the lesser develop-

[1] Actually even this line has been completely open only since 1926.

ment of fans, while Münster, the largest village, with more habitations marked at this one centre than on the whole opposing valley-side, lies on the largest fan of all, built from the waste of the Münsterthal and (probably to a larger extent) of the corrie-like depression cut back into the valley wall at this point.

But were the presence of fans the one factor influencing settlement we might expect a more marked utilization of the fans of the transriverine valley-side—*e.g.*, that at the confluence of the Eginen tributary, which succeeds in pushing the Rhone in a marked bend toward the opposing valley wall.

It is rather by reference to the compass points that the real cause for the marked contrast in the value of the two valley-sides is explained, and this applies equally to Map XIV and to Map XV. Both valleys trend from north-east to south-west; therefore there must result a great contrast in the intensity of insolation on the two sides of the valley, so that in both maps there is striking evidence of the concentration of settlement upon the sun-facing wall. Thus we may equally well speak of the sun-facing and shaded sides as of the village and transriverine sides of the valley. This fundamental importance of aspect is revealed whether we study the distribution of habitations in general or in detail. Thus though the villages are clearly placed on the alluvial fans (Map XIV), their position is not central, but on the sun-facing south side of the fan. The importance of aspect is again illustrated when we study the settlements of the transriverine, sunless side. Here there is only one locality where the habitations rise to any considerable altitude up the valley wall—namely, at the head of the Eginen gorge, just where there occurs the one marked south-facing slope on this side of the valley.

When the actual altitude at which the villages occur is noted (*i.e.*, approximately 1350 metres), then the greater value of the sun-facing slopes may be appreciated readily, Obergesteln surely must lie near the upper limits of permanent settlement. Likewise, the combined influence of altitude and aspect may have determined the commune form, a type

which, as previously noted, is of fairly common occurrence in valleys of similar cross-section and orientation, and where, therefore, the same pronounced contrast in the value of slopes would occur. Thus because of the disadvantages of the shaded side the chances of separate commune growth on both sides of the valley would be minimized. Instead, the present unit has grown to include the complete valley section previously described.

We may note one final relationship which can be traced quite clearly from Maps XIV and XV—namely, that of forest to habitations. Particularly in the Rhone valley the uneven distribution of the forest is conspicuous. While it clothes the north-facing, sunless side almost continuously from a lower altitude of approximately 1400 metres to an upper limit of about 2000 metres (above which it changes presumably to alp pastures), yet on the sun-facing, populated valley-side the forest zone is practically non-existent, except for a few isolated strips. Below Münster, however, a larger zone does occur, but here it is noticeable that the lower limit seems to be at about 1650 metres and the upper limit at about 1900 metres—*i.e.*, the lower limit is *higher* and the upper limit is *lower* on the sun-facing as compared with the sunless side.

A second conspicuous feature is the location of habitations where there is absence of forest. This is especially noticeable on the forested valley-side, where any break in an otherwise almost continuous forest cover is immediately marked by at least one habitation (see particularly the two small clearings near the upper forest borders—*e.g.*, opposite to Geschinen on the higher slopes). Correspondingly, we may note how in general it is the forestless side of the valley which supports the densest population. Therefore from all standpoints there is a most pronounced contrast in the two valley-sides: sunless *versus* sun-facing, scattered and sparse occupation *versus* consolidated and dense settlement, and, finally, forested *versus* partially deforested.

In using the term deforested it is implied that formerly the forest cover was present over the sun-facing slopes perhaps to the same extent as it is to-day on the sunless side.

How far does the map suggest that it is definitely deforestation which has occurred—*i.e.*, that the absence of forest is a result rather than a cause of settlement? We may first recall the narrower vertical range of forest growth on the sun-facing side of the valley as traced in the case of the largest area still remaining, below Münster.[1] This is exactly what we should expect to find where there has been interference with natural forest distribution, for the forest belt would be gradually cleared for the extension of agricultural land from below and of Alpine pastures from above. Furthermore, the last traces should in this case be left in the middle altitudes of the original entire forest belt, which again is exactly what may be found—*e.g.*, in the case of the isolated strips of woodland above Obergesteln. The entire absence on many of the steeper slopes above the villages may be an indication of complete deforestation, perhaps related to exploitation for building material, fuel, etc., and reflecting the great economic value of forest in an environment of this kind. But it is dangerous to stress the importance of deforestation as the sole factor governing present distributions. The thin soil which such steep slopes must guarantee to be present will become dry under the intense insolation of the summer season, and therefore forest growth may at least be limited, though not actually prohibited, on the sunny as contrasted with the shaded valley wall. It is of interest to notice in this respect the existence of forest on the shaded and not the sunny side of the little tributary ravine above Ulrichen, illustrating the value of assured moisture and shade in relation to tree-growth.

Studying the boundary of the forested areas more closely, we find further testimony as to man's interference. Normally one would expect to find a gradual transition from the forest belt into the alp, but here in many places (particularly above Münster) the boundary is distinct and angular, and

[1] This little stretch of forest-land is actually continuous for a considerable distance beyond the limits shown on the map, and is therefore a safer line of evidence than perhaps this map alone would lead one to realize.

the forest definitely enclosed, suggestive of an encroachment which has taken place in strip-like clearings. This patterned border is even found at the upper forest level of the heavily timbered slopes on the sunless side, and suggests that here too the alp belt has been artificially widened. In this latter case it would certainly seem more advantageous to clear the less steep and unshaded upper forest borders, and so extend Alpine pastures, than to extend the deforested zone from below over the relatively valueless, excessively steep and sunless slopes of the forested trough walls.

Sun *versus* shade has, then, been the primary influence in the spread of settlement and perhaps, too, in the associated forest clearance. The definite enclosure of so many sections of the forest border suggests heavy exploitation by the inhabitants in the past, reflecting the difficulties of re-afforestation in regions of such steep slope and rapid soil-wash, and hence the need to regulate further deforestation to-day. In passing we might be tempted to suggest a possible relation between the larger alluvial fan belt (also the greater headstream erosion) and the deforestation of the valley-side. The protective influence which the forests of the sunless side may seem to have exerted can be appreciated when one reads the map evidence of altitude and exposure (which imply rapid rock disintegration) and likewise of precipitous slopes (suggesting avalanche and rapid soil-wash where there is no protection by a vegetation cover).[1] Though the influence of the forest in this respect may be considerable, we may equally relate the contrast in river action to the physical factors discussed previously in Chapter VI, and which have been active during so much longer a time period.

It remains to comment on the approximate equal value of the upper alp pastures as measured by the number of habitations (20 on both sides). This suggests that the contrast in value of the sun-facing and shadowed sides which exists at the bottom of the trough is minimized when one

[1] On the Swiss map avalanche walls are marked on the treeless slopes above the villages. (See the slopes above Geschinen, Map XIV.)

has climbed above the shoulder to the less shaded and gently sloping alp.

We may summarize from Maps XIV and XV the essential characteristics of the human geography of many Alpine valleys, where foci of the population occupy the most favoured parts of the main valley, but a year divided between seasonal migrations from the centre to the highest alp of both valley flanks warrants a transverse rather than longitudinal local human unity.

Before leaving the study of the truly Alpine region we should consider briefly the human geography of Map XVI, A, which illustrates a region contrasting in many respects with that of the two areas previously studied, though these contrasts are ultimately dependent upon the same basic influences. Whereas in Maps XIV and XV the main focus of the population is shown to lie within the valley, in Map XVI, A, conditions which are the direct antithesis are portrayed. Indeed, at first glance these seem almost anomalous, for in this region, although road and railway run quite normally along the main U-valley floor, yet they pass through a region almost completely devoid of habitations and bounded by steep walls, still very largely forested. Not one village, nor even a single isolated church, lies along this main highway; and indeed to the traveller who keeps to the main road the region must seem all but deserted, for the entire population centres on the terraces of relatively gentle gradient above the valley. The railway at *x* appears to serve no village or population until we follow the winding road leading by hairpin turns to Waltensburg above. Notice, too, the number of churches present once one climbs on to the more gentle slopes above the U-valley gorge.

The geographical *rôle* played by the main valley (at least for local, if not for regional relationships) is directly opposed to that which characterizes either of the regions previously discussed, particularly the Rhone valley. Whereas in the latter instance the valley is the link to which all settlement gravitates, here it is the divide—a barrier zone which tends to isolate the population of either valley-side. This contrast in value is reflected in the form of the commune. No longer

does this include a complete transverse section of the valley, but is rather a longitudinal zone, in some cases including the upper terrace slopes only. For example, we may note how part of a commune boundary trends along the upper margin of the southern valley wall, suggesting an isolated or relatively separate interest of the inhabitants on each upper bench flanking the Vorderrhein trough.

The change in the character of settlements can be traced, however, to the interaction upon the topographical detail of the three same fundamental influences—altitude, slope, and aspect. Thus in the first place the main valley lies at a much lower altitude—750 metres as compared with 1300 metres in the valleys portrayed in Maps XIV and XV; therefore the regions upon which settlement concentrates actually lie at approximately the same altitude as in the areas previously discussed. Furthermore, the zones of gentlest gradient (with the exception of the U-valley floor—obviously in part waterlogged) all lie high above the steep main valley walls, extending beyond to north and south in broad and comparatively gently sloping terraces. Thus degree of slope adds advantages where altitude does not negative settlement. Finally, the search for the sun—*i.e.*, the influence of aspect—all but prohibits settlement in the main U-valley, in favour of the gentler slopes above.

To appreciate fully the latter influence we may turn to Figs. 23 and 24, which attempt to give an actual picture of the amount of sunshine that valley *versus* upland, or sun-facing *versus* north-facing slope, receives. Latitude is marked on the Swiss maps (if the small sheets of the "Siegfried Atlas" rather than the large combined sheets are used), and from this it is possible to calculate the altitude of the sun at noon on December 22 and June 21—*i.e.*, at its minimum and maximum intensity. Thus for this region (latitude approximately 47°) the equinoctial altitude of the sun will be 43° (*i.e.*, 90 − latitude) and that on the winter and summer solstice $19\frac{1}{2}°$ and $66\frac{1}{2}°$ respectively (*i.e.*, (90 − latitude) $\pm$ $23\frac{1}{2}°$). Figs. 23 and 24 are drawn by plotting these angles at points along a section drawn without exaggeration of the vertical scale, and the result

gives an interesting and relatively accurate picture of the intensity of insolation, indicating regions of maximum sunshine. Fig. 23, showing conditions at the winter solstice, is perhaps the more instructive of the two diagrams. Particularly noticeable is the extreme contrast in the size of

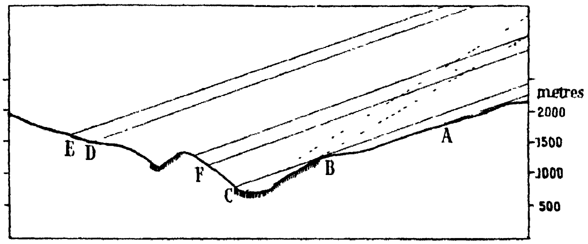


FIG. 23. SECTION FROM NORTH TO SOUTH ACROSS MAP XVI, A, TO SHOW INTENSITY OF INSOLATION AT WINTER SOLSTICE

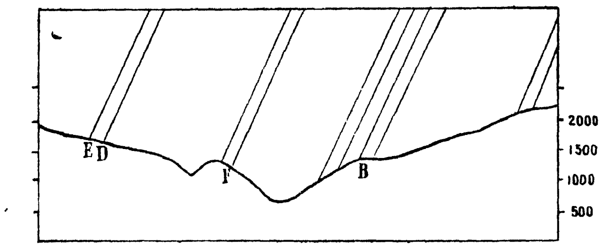


FIG. 24. TO SHOW INTENSITY OF INSOLATION AT SUMMER SOLSTICE

In both diagrams horizontal and vertical scale is the same—*i.e.*, 4 mm. to 500 metres.

the area over which the sun's energy is expended between points A and B and D and E from rays of the same width. This portrays the winter sun just glancing over the north-facing alp slopes, in contrast to its influence as a real warming power on the opposite valley-side. Similarly can we visualize the more rapid rise of the snow-line on the sun-facing slopes, so much more intensely heated in early spring.

Of especial interest, also, is the main valley section between C and B (Fig. 23), for this all lies below the ray BA. Thus on midwinter's day even at noon the sun will not rise

high enough to shine (no matter how obliquely) on the valley bottom or the north-facing wall between the points C and B. Were this valley floor permanently inhabited, there would be—at least for many sections—considerable periods of the year when the sun was never visible to the villagers; it is not surprising, therefore, that almost all of the habitations are found on the terrace above, leaving the main valley as a unit important regionally rather than locally—simply as the obvious route for predominantly through traffic.

When the sun's altitude has risen to the position indicated by the dotted lines, then a gleam of sunlight may fall just momentarily at midday in a long, oblique shaft across the summits of the dark pine-forests which we may visualize as clothing the north-facing wall. Now the angle of this dotted ray is 31°, indicating, therefore, a position midway between the angle for the winter solstice (19½°) and that for the equinox (43°). This should imply that from early November to mid-February no sunlight can ever fall on this forested wall, while during December at least almost the whole valley floor will lie in sunless gloom. But it is suggested by the relief that even when the sun rises high enough for its rays to enter the valley the energy will probably be expended in warming the upper surface of a 'glacier' of mists and fog resulting from the excessively cold air probably gravitating into, and thus filling, the old ice-worn valley.

In view of the distribution of sunlight, it is a little surprising to find that valley habitations tend to cluster thickly on the *north*-facing side. This distribution suggests that at least they can be occupied only seasonally, while their position is explained when we examine the detail of the valley floor. It is on the south side that there occur the largest areas of flats which are not waterlogged.

Viewed as a whole, therefore, settlement in this region is particularly related to the more gentle upper slopes, partly because of the greater opportunities which we may assume these to guarantee for agriculture or pasturage, and also (perhaps to a much greater degree) because of the longer exposure to direct insolation, the importance of which is

revealed when we compare the density of settlement on the two opposing terraces. For in spite of their importance on both sides of the valley, it is the sun-facing terrace which possesses the densest distribution of habitations and the main foci of the population—*i.e.*, the two large villages at X and Y. That these latter are the more important centres of the whole area is indicated not only by their relatively large size, but also by the fact that the railway-station in the main valley at *x* is named after the village above, to which it is linked by the winding road previously cited.

It is interesting to compare the plan of the villages with those depicted in Map XIV, for both reveal contrasting local geographical influences. Whereas in the one area consolidated villages have grown on the favourable site afforded by the alluvial fan, here, in contrast, they represent settlements in forest clearings, typified by the line of habitations placed beside road and mule-track on the sun-facing terrace above the Vorderrhein. Just as some Wealden villages (Map III) show traces of the "ring fence" pattern indicative of early settlement in forest clearings in a region of relatively low relief, so the present form typifies settlement in mountain forest clearings, thus exemplifying a definite class of rural settlement.

Apart from the distribution of habitations, we may finally trace the influence of aspect in the extent of deforestation. In the first place, forest now remains as a continuous belt in the shaded main valley, while it is largely cleared from the terrace slopes above. Further, in viewing the sun-facing side alone, we may note how much greater is the extent of deforestation within the gorge on this side as compared with the north-facing wall, while, again, on the upper terrace a marked area of forest remains flanking the shadowed side of the small stream passing from Y through X. (See Fig. 23, which shows how unfavourably placed is this slope as regards winter insolation.)

Map XVI, B, supplements the previous area, illustrating particularly the influence of slope on settlement and deforestation, more especially as related to the utilization of even the small, isolated bench relics which occur at intervals

along the steep side of the glaciated valley. Here they are clearly outlined by the line of deforestation, particularly in the case of the bench relic at C. Equally noticeable is the long slope between A and B, where the forest edge precisely follows the corner around which each contour abruptly bends at the point where the steep wall of the main Rhone valley truncates the side of a more gently graded tributary wall.

And as we turn from the study of the Swiss Alpine valley we may pause to note an interesting if chance coincidence—namely, the similarity between the character of settlement in these isolated valley sections and the historico-geographical *rôle* of the larger river systems to which each area individually belongs. The upper Rhone valley (Map XIV), with its concentration and gravitation of settlement on or near to the valley floor, reminds one of the age-long importance of the Rhone valley system as a great *couloir* within which movement has tended to take place. The section of the Vorderrhein (Map XVI, A), where the main valley divides rather than unites, epitomizes the use of the larger Rhine system as a through highway mainly for traffic from outside, and reflects (if but by a very local illustration) the great frontier *rôle* which the river has played throughout history.

The survey of glaciated regions would scarcely be complete without reference to the human relations depicted on the Ordnance Survey British maps. These represent areas of far lower altitude, and less isolated environment, where characteristic land-forms are developed on a much smaller scale than in Switzerland. In most cases, therefore, one can identify only the more general human relations. But alternatively it is often possible to view in a relatively small area inter-relations between neighbouring valleys which could be studied only on a large number of adjacent Swiss sheets, owing to the magnitude of Alpine relief features. In this way the British topographical map frequently gives a useful small-scale or 'bird's-eye' summary of the essential features of the local human geography of such regions, yet seen at the same time in a broader regional setting.

This is well illustrated in Map XIX, where the dominant

human characteristics are seen to be, firstly, the relative poverty of the region and the resulting sparsity of population, and, secondly, the concentration of settlements within the main valley—presumably the region of greatest attraction both by reason of the greater available areas of fertility and because of the natural concentration of the only railway and the main roads along this obvious line of easy movement.

In detail, it should be noted how settlement within the Conway valley is exceedingly characteristic, and likewise reminiscent of that within the Swiss valleys studied in Maps XIV and XV. For the villages, together with road and railway, marginally flank the U-valley side. Particularly the villages seem to lie at the meeting of tributary and main valleys. In the case of Bettws-y-Coed and Llanrwst, their position is clearly related to the convergence of routes, which in a region of restricted facilities for intercommunication must always possess considerable value. Of the two villages Llanrwst is by far the larger—indeed, it is the largest village of the whole valley, the reason being clear (especially if the full Ordnance Survey sheet is consulted) when one notes not only the more gradual rise to a plateau of lower altitude, but also the very distinct breach of this eastern plateau by converging tributaries, which provide relatively easy and direct routes from Llanrwst north-eastward to the coastal plain at Rhyll (see full sheet 107, "Popular" edition).

But there are other villages (*e.g.*, Trefriw and Dolgarrog) similarly placed at the junction of tributary and main river, though in this case the tributary valleys are very largely isolated *culs-de-sac*, followed neither by road nor, in some cases, even by footpaths. But the very inaccessibility of the upper tributary valley—large or small though it may be—often implies an advantage in close contact with the stream below, for the upper inaccessibility is determined by the presence of gorge and falls in the lower tributary reaches, marking the adjustments to a former hanging valley by post-glacial river action. Thus there is provided by the natural steep stream grade and the actual falls the power

for the driving of innumerable mills, which may occur frequently at these positions and foster local village industries (of which we have probable evidence in the woollen factories at Dolgarrog).[1]

Since, as has been suggested earlier (Chapter III), the region is composed of old and hard rocks, strongly resistant to the forces of denudation, it is not surprising that there are indications of metal-workings and slate-quarrying, especially within the tributary valleys. Thus the Trefriw valley leads on the north to sulphur-workings and on the south to lead-mines and slate-quarries.

But a feature of especial importance in most glaciated mountainous regions (and which cannot be studied from the restricted sections of Swiss maps included in the envelope) is the great value of the through valley in determining the trend of communications. The significance of this land-form is as great in the interpretation of human as of physical geography. Thus in spite of the boldness of the relief there is relatively easy and direct communication by first-class road *via* the exceedingly low through valley-pass at X. Similarly may we notice how the absence of a divide between the valleys of Glaslyn, Llanberis, and Gwrhyd results in the branching of first-class roads from Capel Curig along these well-defined routes, thereby illustrating the importance of this aspect of ice work in minimizing the difficulties of transmontane communication. It is interesting to notice in this connexion that only one village lies outside the Conway valley—namely, Capel Curig—a tiny wayside halt at a triple junction of through valley roads.

One symbol of the map permits us to see the value of the district in yet a broader regional setting. We have stressed the importance of the Conway valley as the most attractive zone of settlement, along which trend the main lines of communication, but this significance reveals itself to be purely local in character. For the Conway valley is threaded only by a single-track railway, and, as the full sheet shows,

[1] These mills are marked on the old "Fully Coloured" edition and the "Tourist" edition (1920), although they are not indicated on the "Popular" edition.

is entirely ignored by the main railway-lines trending almost due east to west along the restricted northern coastal plain.

In conclusion, how far is it possible to trace the probable future economic values of this and similar regions?

(1) The first value lies in the tourist industry, of which abundant evidence awaits the map-reader's search in the numerous and scattered hotels and inns,[1] the golf-courses[2] (in this type of topography generally on or near the main U-valley floor!), and, as in the case of Snowdon itself,[3] the mountain railway.

(2) Secondly, we may notice the great value to adjacent external centres of dense settlement of regions abounding in lake reservoirs, as is indicated here by the reservoirs (in large part natural) of Llyn Cowlyd and Llyn Eigiau.

(3) Thirdly, the close association of pipe-line, water reservoir, and aluminium works at Dolgarrog is of very great geographical significance. In the first place, the pipe-line heralds the new industrial era, when full exploitation of the white coal of these regions will be realized, with an associated revival of old and development of new industries. The Vale of Conway in this way affords a striking illustration of the present phase as one still transitional, the close coexistence (within a few miles) of power-station and water-mills indicating the changed value of river energy.

The fact that hydro-electric works lie so closely adjacent to reservoirs and waterworks exemplifies an important tendency in methods of hydro-electric development, where the flood or compensation water from the reservoir works is utilized by the power-station below. Finally, the industry which the power-station would seem primarily to serve (namely, the aluminium works) suggests not only a stage in the reversal of the depopulation of these rural areas, but also the probable future character of industrialization in such relatively isolated valleys. For aluminium manufactures comprise an industry where much power per ton of

[1] These are not clearly marked on Map XIX, but can readily be found on the original Ordnance Survey Maps.

[2] Commonly found marked on adjacent sheets of the North Wales district.

[3] Shown in the south-west of the area on Map XIX.

finished goods must be consumed, and the result is that the industry grows up close beside the power-station rather than that the power be transmitted with considerable wastage to external centres.[1] Thus in harnessing the new power there must come, if only locally, a profound change in a region which has for so long a period remained aloof and but little altered in outlook—a striking contrast in interests and opportunity to industrial England, but a stone's throw to the east.

[1] Compare many other metals manufactured by electrolytic methods, which industries therefore gravitate to the centres of power. See L. B. Cundall and T. Landman, *Wales : An Economic Geography*.

SECTION IV

COAST-LANDS—PHYSICAL AND HUMAN ASPECTS—REGIONAL STUDIES

CHAPTER X

STUDIES OF COASTAL TYPES—PART I

In attempting a simple classification of coastal regions it should be remembered that, at least for general purposes, the physical form of the shore-line depends primarily upon (1) the direction of the last major earth-movements, to produce a shore-line either of submergence or of emergence, (2) the work of the sea as an agent of erosion and deposition, producing modifications which will vary according to the stage attained in the cycle of marine denudation. The more advanced the stage, the more will this second factor dominate to determine the form of the coast.

But both factors are themselves dependent upon the form and structure of the interior. Thus the coast-line of submergence varies according as this occurs in regions formerly of bold or subdued relief, while the rate of marine denudation, no matter what phase of activity is considered, must depend in large measure on the character of the rocks exposed to the attack, and these again are simply the frayed margins of the interior structure.

But whatever the physical environment may be, the human response likewise is not only an adjustment to the coast-land itself, but also (and often to a far-reaching degree) varies according to the intimacy of the physical and economic contact of interior to margin. Thus in map-interpretation it is essential in every geographical sense to consider coastal regions not necessarily as isolated and distinct units, but also in the degree to which their physical and

human associations are determined by interior conditions. It is for these reasons that their consideration has been postponed until now. The identification of some types of shore-lines will be considered from Maps XX–XXV, and the following arguments, though in some respects incomplete, will sufficiently indicate the methods of analysis, which the student can apply to other types not here included.

South Devon Type

Map XX depicts part of the South Devon peninsula, roughly intermediate between, and south of, the external centres of Torquay and Plymouth. Viewed as a whole, the area consists of a low plateau which has suffered quite considerable dissection, though to a varying degree in different localities.

Before turning to a study of the actual shore forms, we should consider briefly the structure of the interior.

In the north a band approximately 2½ miles wide, and relatively openly contoured, indicates a plateau averaging 450–500 feet in altitude, and moderately rather than intensively dissected by rivers which, at least in their upper valley, exhibit youthful features—*e.g.*, deep, narrow coombs of steep gradient, locally exhibiting a conspicuous development of overlapping spurs (see Chapter IV). The southern boundary of this unit trends east and west, between A and B, and coincides for some miles with a section of the Avon valley—*i.e.*, between the points where a road and a railway cross the valley.

In the extreme south a similar zone extends from east to west south of a line which joins Bolt Tail and Salcombe, and is continued eastward along Southpool Creek, to run out to the east coast about a mile north of Start Point. This southern section includes a plateau of noticeably slight dissection, broken only by occasional short and narrow glens. In altitude it maintains an even surface, almost everywhere slightly below 450 feet.

Between these two plateau units there lies a broader belt, in general far more uniformly dissected, by valleys which are slightly more widely opened (noticeably in the case of the

western coastal streams). The maximum elevations here never exceed 300–350 feet, no matter whether we study the peninsula to the east or the west of the Kingsbridge estuary; but it is of significance to notice that everywhere the divides between the narrow valleys rise to a common altitude of 300 to 350 feet, so that again one may identify the dissected plateau, in this case worn to a general altitude about 100 feet lower, and more maturely breached by river action, than in the case of the parallel units to north and south.

This survey of the relief suggests, therefore, the presence of parallel east-to-west outcrops providing a distinct graining in east-to-west belts, the central one of which is seen to consist of less resistant rock, because it is worn to more subdued relief. The small difference between the general altitudes of the northern (450–500 feet) and the extreme southern section (400–450 feet), separated as they are by a distance of about 6 miles, indicates perhaps only a slight degree of tilting when the area was uplifted to form a plateau, while the alternation of rocks planed to a relatively uniform level may indicate the uplift of a plain of denudation rather than of a sequence of horizontal or but slightly inclined strata. Whether the plain was one formed as a peneplain of sub-aerial denudation or a plain of marine erosion it is perhaps hazardous to suggest purely from the evidence of the map. Reference to the full sheet reveals one line of evidence which is not emphasized in the small section shown here. If the plateau is an uplifted peneplain, then powerful rivers of large volume (which would have been the primary agents in levelling the region) should now be rejuvenated to exhibit broad, incised meanders of fairly large radius. A study of even the small section of the Avon shown here illustrates how contrary are actual conditions (*e.g.*, in the upper valley, where this is followed by the railway). Beyond the limits of the region depicted here the Avon throughout its course trenches the open plateau only by means of a sinuous, but not truly meandering course, to produce the overlapping spur rather than the true incised meander bend[1]

[1] On the full sheet examples of definite, if small, incised meanders can, however, be identified in the neighbouring valley of the river Dart.

(see Chapters IV and V). If this is a course inherited from the time when the river flowed over the former plain before uplift took place, then it is difficult to visualize how a river of this form could ever have aided very materially in such widespread planation. If, however, it represents one of the main drainage collectors across a plain of marine erosion which has steadily been raised above sea-level, then an apparently anomalous absence of true incised meander bends is readily explained, since the plain was made before the present river system developed upon its surface.[1]

To return to the main theme, however, we have traced a probable occurrence of broad outcrops which vary in durability and strike in an east-to-west direction. This is exemplified in greater detail by a study of both major and minor river systems. These disclose a strong tendency toward the evolution of a patterned system, such as would be dependent upon the existence of subsidiary lines of least resistance trending parallel with the strike of the beds. When viewed in relation to adjacent regions, the present area is seen to comprise the southern part of a plateau sloping gently southward from the borders of the Dartmoor plateau; therefore the main consequent drainage direction initiated upon that slope trends approximately from north to south, and is exemplified by the upper course of the Avon and also the Kingsbridge estuary. The latter will not be considered in detail at the moment, except to notice how this broad inlet is fed by small streams rather than by normal-sized rivers with proportionately larger tributaries. This fact becomes of great interest when it is noted how the upper Avon follows a direction quite normal for a river about to enter the Kingsbridge estuary rather than the present Avon mouth. Only a small part of the north-to-south Avon valley can be seen on this section of the map, but this feature can be exceedingly clearly read from the full Ordnance Survey sheet (see Fig. 25). There seems strong evidence to suggest that the

[1] In this connexion see the articles by Dewey in the *Quarterly Journal of the Geological Society*, vol. lxii, pp. 63–77 ("The Origin of River Gorges in Cornwall and Devon"), and in the *Geological Magazine*, vol. v, April, 1918 ("Land Forms in Caernarvonshire"), where upland plains at a present altitude of 430 feet are identified in both regions as due to marine erosion.

lower Avon (as a subsequent flowing approximately from east to west) has at some period cut back to behead the older Kingsbridge river at a point only a few miles above the present head of the inlet, to form a beheaded estuary

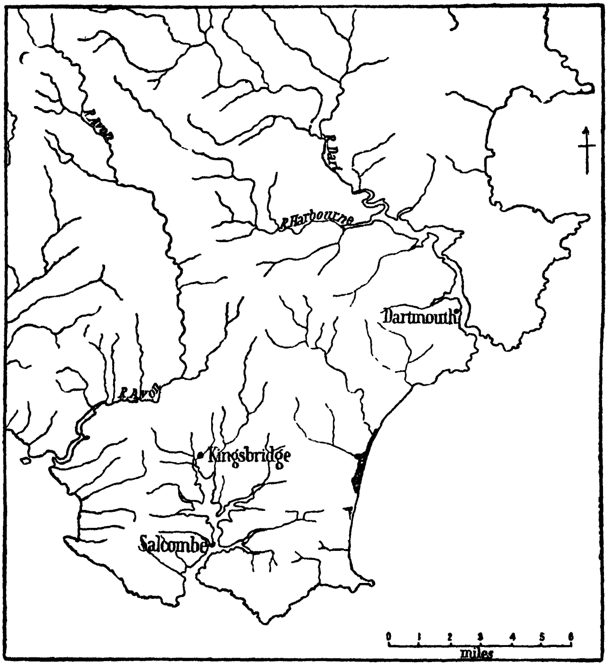


FIG. 25. DRAINAGE SYSTEMS OF SOUTH DEVON

rather than a beheaded river at the present time. The angular turn of the Avon valley where the railway leaves the Avon to tunnel through the plateau to Kingsbridge may therefore represent the elbow of capture.

It is possible that capture occurred at a very early stage during the uplift of the plain, to form the present plateau long before the present altitude was attained. In any case, the Avon valley both above and below the elbow of capture has become incised considerably since the assumed capture took place; thus the surface over which the river once

flowed (north of Kingsbridge) now lies at an altitude of 400 feet, while the Avon valley to the north has been cut down to a height scarcely 50 feet above sea-level. The section of the valley which coincides with the direction between A and B may follow a line of least resistance, demarcated by the assumed change in rock structure or texture.

Equally significant is the trend of the small valleys in the central section, comprising the more maturely dissected plateau. The road between Kingsbridge and Salcombe follows the water-parting between a series of *pairs* of small rivers, each one trending from east to west, or *vice versa,* in alignment with its neighbour across the divide. Some of these east-to-west lines of least resistance can be traced continuously eastward beyond the Kingsbridge estuary. It is instructive to notice how frequently a line of valleys follows the edge of a ruler which is placed in a series of east-to-west positions across the map. Again, the main road from Kingsbridge to Slapton Ley follows a marked east-west depression, in this case, it may be noted, not entirely occupied by running water. Between C and D a conspicuous line of valleys can similarly be identified. These features all afford further proof of the east-to-west grain of the land, and perhaps of the existence of some further factor—such as pronounced east-to-west major jointing or actual dislocation—which provides additional regular lines of weakness in the same direction. It is impossible to tell from the map alone what the exact nature of such a structural weakness may be.

From a study of the interior one may turn to an examination of the coast margin, to ask the following questions: (1) How far does the form of the coast and work of the sea substantiate the above deductions as to the general rock structure and texture? (2) How far may an interpretation of marine erosion add additional information regarding the nature of the rocks, etc.? (3) To what extent, if at all, does the map provide evidence either of submergence or of emergence, and how far may the resulting coast features have been modified by marine denudation?

In practice it will generally be found that question (3) should be considered at the outset, before any logical dis-

cussion of marine denudation can be presented, or any attempt be made to decide the relative importance of these two fundamental factors (earth-movements and marine denudation) in accounting for the evolution of the shoreline under consideration. In the present instance ample evidence may be collected to indicate the influence of submergence as fundamental to the coastal form as a whole, though to a varying degree in different localities there are modifications produced by a movement of slight emergence, together with the influence of marine erosion and deposition.

Perhaps the most outstanding feature of the coast-line is the broad and branched inlet which leads from Salcombe to Kingsbridge, effectively bisecting the southern peninsula. In outline it continues the bends of the valleys which lead to the estuary. The tide penetrates as far as Kingsbridge, and at high water almost an irregular-shaped 'lake' of sea-water spreads east and west—in some cases for several miles, when the sea covers all the areas stippled on the map (and which mark the extent of the tidal flats). Correspondingly, at the time of low water the whole of this area is uncovered, while dwarfed and braided channels slowly flow seaward amid a broad, and probably in large part waterlogged, mud flat equal in area to the former high-water 'lake.' In short, this exemplifies a typical inlet of submergence, where the sea has entered to drown the lower basin of a formerly united river system, the tributaries now being dismembered from the trunk stream to form separate tidal creeks. Buried beneath the present flats there should lie the continuation of the tributary valley walls. The tidal flats are steadily growing seaward, and ultimately will fill the inlet from side to side, to build a flat plain smoothing over all underlying submerged topography, whether low ridge or vale. The size of the inlet seems the more striking when one recalls the disproportion between this and the diminutive rivers which drain into it (see Fig. 25).

It is of the utmost importance to remember that submergence has occurred in a region comprising bold rather than subdued relief; this results in the isolation of abrupt headlands between adjacent creeks, so that more precisely

one may class the inlet as a ria in spite of the name "Kingsbridge estuary" supplied by the map. In passing it may be recalled that Gregory would designate this inlet as a fjard, using the term in a widened sense to include the non-glaciated, fjard-like indentations together with true glaciated fjards. If this view is correct,[1] then the trend of the inlet has been decided by dissection along planes of fracture determined by dislocation (or faulting), with subsequent submergence to form a bay of patterned form, dependent upon the angle at which fracture lines intersect. From the topographical map alone one can only attempt to corroborate this view by noting the presence or absence of a regular patterned form. In this respect the prevalence of north and south, north-east and south-west, and north-west and south-east sections of shore or creek boundaries suggests the intersection of fracture planes at angles of 90° and 45°. The coastline from G to Bolt Head parallels the north-to-south inlet between Salcombe and Kingsbridge. At G there is an abrupt right-angled bend north-east to Salcombe and south-east to Prawle Point. In detail, a diminutive bend at Bolt Head repeats the same direction and right-angled pattern. The creeks north of Salcombe either repeat the north-east and south-west and north-west and south-east directions of the shore-line to the south, or trend from east to west—*i.e.*, at right angles to the general north-south direction of the main estuary (see Fig. 26).

Of significance in connexion with the possible tectonic relations of the lines of the inlet is the frequency with which portions of the coast beyond appear to follow the same system. Thus the part of the coast from Salcombe to G parallels that from Prawle Point to E and from Start Point to F. The coast between E and F repeats the small east-to-west section at Bolt Tail or Southpool Creek (due east of Salcombe). Again, Bolt Tail to Bolt Head parallels the line from Prawle Point to G. Yet more interesting is the fact that the river Avon takes two distinct bends to flow in three very definite directions—viz., (1) due north to south, (2) east to west, (3) north-east to south-west. All are directions

[1] See J. W. Gregory, *The Nature and Origin of Fiords.*

which repeat the pattern of the south coasts, and seem to suggest the occurrence at least of master joints, if not of lines of definite dislocation, following these directions. The last direction of the Avon (north-east to south-west) demarcates a section of the valley subject to submergence at high tide, and the long stretch of tidal flats seems again to

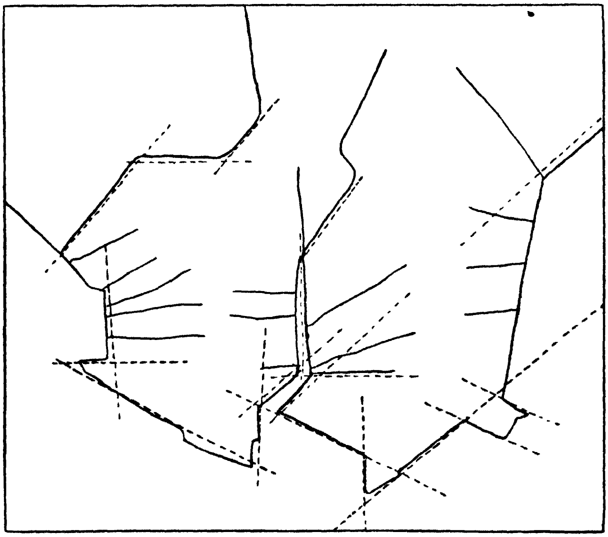


FIG. 26. THE PATTERN OF LINES OF WEAKNESS DEDUCED FROM THE TREND OF COASTS AND DRAINAGE

indicate the presence of a submerged valley repeating the direction of the inlet between Salcombe and G.

Sedimentation seems more nearly to have converted the Avon estuary or ria into a long flat than is the case within the Kingsbridge inlet. Partly will this be due to the difference in their size, but more important may be the contrast in the volume of the rivers entering these bays; thus a larger river carries a correspondingly heavier load into the smaller Avon inlet. Although at high tide the sea may sweep some marine-derived sediment into these relatively quiet backwaters, and also will sort and to a certain extent redistribute the fragments present (whatever may be their origin),

it is the load deposited by the rivers in deltaic downstream growth which seems to play the primary part in the complete aggradation of the estuary. To a certain extent one may visualize marine action as even retarding deposition within parts of the Kingsbridge inlet, for it is almost bottle-necked, opening broadly once past the restricted 'narrows' through the more resistant southern plateau. There may be some tidal scour through the neck near Salcombe.

In the valley above the tidal flats of the Avon inlet a flat plain extends for about 3 miles, over which the Avon meanders freely, in part with a braided channel. The meanders are of relatively small radius, and the misfit river provides evidence suggesting that at least part of this upper valley may at one time have been submerged, since when sedimentation has converted the inlet into the present flat. According to the evidence of the spot heights on the Ordnance Survey map, the plain is only 11 feet above sea-level 1 mile above the tidal limit. In time the whole reach of valley which is at present submerged at high water may become converted into a plain of similar form. (Compare in this respect the origin of the flat floor of the South Wealden water-gaps—see Map III and Chapter IV.)

Raised Beaches. In the search for evidence of earth-movements the reader's attention has probably been arrested by the words "raised beach" printed beside Slapton Ley. This information is supplied on the original Ordnance Survey sheet, but it should perhaps be remarked that this is an unusual procedure. It is possible, however, to identify the raised beach without the aid of such direct information. A very careful study of the shore-line may reveal its presence, particularly on this map, in the neighbourhood of Start Point and Prawle Point.

Considering first the stretch of shore-line immediately to the north of Start Point, we may identify here quite a conspicuous if narrow flat, the outer margin of which definitely lies above normal storm-wave action, for a small village is located here. But behind this narrow flat there is a very pronounced cliff of no inconsiderable altitude, which seems to represent the front against which wave action formerly

broke. Thus a narrow coastal fringe has been raised above marine action. It may, however, be argued that this flat might equally have grown by normal processes of marine deposition, and this does not necessarily postulate any uplift of the land. At least in the case under review it seems possible to show that the latter suggestion is untenable, for the foreshore in large part consists of a wave-cut terrace and exposed reef rocks, and, except toward the north, there is no trace of beach accumulation such as would be in keeping with a region where coastal deposition is taking place.

Equally if not more convincing is the evidence of the coast west of Start Point. A very careful scrutiny of the shading on the Ordnance Survey map reveals the presence of cliffs of variable height (though generally under 50 feet) immediately bordering the shore and facing a wave-cut terrace below. But above the low cliff there lies in many places a narrow flat, widest just to the west of E, in the bend of the coast. This flat again is backed by a steep rise, which seems to afford evidence of a raised cliff-face behind the raised beach terrace. In many cases the latter feature is followed by a footpath, the land-form thus providing the route for the only means of communication which lies high and dry, though restricted in width, above the cliffs now being cut at a lower altitude. In some places traces of cliffs seem to occur several hundreds of feet above sea-level. It is hazardous to suggest that they necessarily represent old sea-worn cliffs now raised to this elevation, for they might result simply from normal rock disintegration, especially if the rocks tend easily to cleave and form precipitous, cliff-like faces. But the fact that they border the shore-line alone and occur nowhere inland seems evidence in favour of marine action rather than rock texture as an explanation of their origin. Furthermore, though separated by several miles, the different relics of cliff seem to occur at a common altitude, approximately 250–350 feet above sea-level. That the feature can still persist so clearly (if the cliffs are really in part due to former marine erosion) indicates a rock of extreme durability, and one only exceptionally slowly weathered.

Broadly speaking, therefore, the major coastal features of the region seem to have been determined by considerable submergence, forming extensive drowned valleys, but more recently a small upward movement has left the land slightly raised above the level of former wave attack. Confirmation of these latter surmises is definitely provided by the interesting if unusual record at Slapton Ley.

Marine Denudation. Leaving the discussion as to evidence of earth-movements, we have yet to consider the work of the sea in answer to questions (1) and (2) asked on page 190. The occurrence of four bold headlands to the south suggests that the southern section of the peninsula consists of very resistant rock. Bolt Tail and the district around Start Point seem to demarcate very clearly the northern limits of an east-to-west zone of very resistant rock, and this suggestion coincides with the previous deductions based upon the undissected nature of the interior plateau. In spite of the exposure of the southern headlands to strong wave action, there is maintained persistently a shore-line of rugged topography which everywhere seems bordered by a rocky terrace and wave-cut platform. In places small islets and rock pinnacles have been isolated from the mainland, while in general there is a very conspicuous absence of sands and detrital shore deposits. These features all characterize not only a coast exposed to strong wave action, but also a land which yields but slowly to the attack.

Some measure of the slow rate of advance is indicated by the diminutive headland peninsula at Bolt Tail. This remarkably abrupt and naturally defended promontory is crowned at its western extremity by an ancient Celtic camp, not as yet undermined by wave attack and cliff recession, in spite of the exposed position which it occupies. The frequent use by prehistoric man of abrupt promontories of this kind lends weight to the suggestion that the sea-bordered cliff never lay very far from the camp-site, in which case the amount of land destruction since this early period may not have been considerable. Only the minor coves which indent the whole southern shore-line (and perhaps indicate local lines of lesser resistance) and the presence of offshore

rocks and islets testify to the ultimate destructive work of the sea; a resistant land border is a certain though slow loser to the attack of strong wave action.

Along the coast to the north of Start Point the rock platform extends only for a distance of about 1 mile, beyond which it is replaced by sands; thus the wave-cut terrace extends almost to the very position where the east-west limits of the undissected plateau run out to the east coast. North of Bolt Tail the shore-line recedes deeply into Bigbury Bay. This re-entrant seems very clearly to coincide with the assumed zone of softer rocks where in the interior a lower plateau has been more maturely dissected. But though both interior land-forms and embayed coast suggest the differential erosion of less durable rocks, the foreshore is characterized by islets and wave-cut terraces rather than extensive beach accumulations, suggesting that even here the rocks, though relatively soft, are not very rapidly eroded.

Bigbury Bay and Start Bay exhibit shore-lines of rather contrasting form when considered in detail. Whereas the former is markedly indented, the latter presents a regular, smooth curve. The contrast seems due to the varied work of the sea in each bay—related probably to the different degree of exposure and the direction of littoral currents in each area. The result is that whereas Bigbury Bay, exposed to the full force of the south-west Atlantic breakers, is very much indented in form, and subject to heavy marine erosion, with but little deposition except within the coves, Start Bay, on the other hand, occupies a more sheltered position, where both erosion and deposition combine to produce a shore-line of mature form. This, when examined in detail, exhibits many features of interest.

The nature of the drainage and the plateau dissection has determined that alternate valley and spur run out to the coast. In Start Bay the spurs must originally have extended some distance seaward of their present position, while the sea may formerly have entered some of the valleys. Marine erosion has, however, truncated the seaward margin to form a cliff, which as it has receded landward has grown in height. Recession has continued sufficiently far to produce a straight

coast-line bordered by beach deposits. This type of straight shore-line, where bold, truncated headlands are separated by narrow valley flats, is epitomized particularly well in the section immediately to the north and south of C. Similar spur ridges run out to the sea on the western shore (Bigbury Bay), but these, in contrast to the former examples, possess a relatively gentle seaward gradient, and therefore the cliffs are either absent or of much lower altitude in this region.

One of the most outstanding features of Start Bay is the presence of coastal lakes between B and C. The lake at C is triangular in shape, and lies at the mouth of a valley between two truncated spurs. The form and position suggest an origin due to longshore drift of beach material across the valley mouth, the impounded river in this way forming a freshwater coastal lake. The much larger lake at Slapton seems to have been formed by the overflow and union of water in three blocked valleys, which are separated from each other by no such bold headland as that between Slapton and lake C. It is probable that the larger Slapton lake originally extended much farther back up the valleys, for extensive marsh occurs in this direction, illustrating the ephemeral existence of almost all barrier lakes, for they tend rapidly to become overgrown with vegetation and filled with the products of land waste.

It may be recalled that pronounced longshore drift cannot develop on the youthful, deeply indented coast-line (such as occurs, for example, on the south and west coasts of this region). But in Start Bay, as already described, the headlands have receded to a common front, and thus the minor eddies following the curves of small coves and bays can be (indeed, we may almost definitely say have been) superseded by a longshore drift across the valley mouths. The naming of the raised beach at Slapton Ley on the original Ordnance Survey sheet is of additional value in explaining the persistence of the lake, since barriers of this kind are often unstable and liable to be breached by storm waves. It explains also the fact that a main road can exist in this position, with, in addition, the larger part of two villages and a hotel on the *seaward* side of the road, for on a

raised beach not only is the deposit older, and perhaps therefore more consolidated, but it lies above the level of normal wave action.

Traces of similar small lakes or marshland can be identified at comparable positions in valley bottoms leading to Bigbury Bay. It is quite possible that the marshes may represent plains of deposition built up since the former submergence of these lower valleys. But as there is undoubted evidence of a low raised beach forming the seaward margin of the Slapton lakes, and since strong longshore drift (which by itself can form a barrier) seems unlikely to characterize so youthful a shore-line as that of Bigbury Bay, then the presence of the raised beach in this latter region seems the more natural explanation of these features.

The Human Response. It is surprising to find that in this prominent portion of a country famous for its associations with the sea almost all settlement is drawn toward an inland position, to form small agricultural communities. Those boldly named represent villages possessing a parish church or a population exceeding 300.[1] Smaller lettering denotes the village (or, it may be, hamlet) of less than 300 inhabitants.

The characteristics of the whole region in many respects are epitomized by a study of the settlements within the south-western peninsula—*i.e.*, between Salcombe and the lower Avon estuary. Here, although the chief villages must lie practically in sight of the sea, there is little to indicate any general or intimate contact with it. There is only one small coastal village, presumably of fishing interests, which nestles in the sand-bordered and cliff-backed indentation at Bolt Tail. That almost the whole interest of the remaining rural population is related to agriculture seems clear from (1) the inland placement and form of the villages, (2) the many orchards, which often form the setting amid which the village or hamlet dwellings cluster, (3) the presence of scattered farms and hamlets, and (4) the presence, almost without exception, of fenced roads. The latter feature is especially significant when it is noticed on the original sheet

[1] According to the evidence of the type of print employed on the original Ordnance Survey sheet.

how, with but one or two quite minor exceptions, the roadways are either "indifferent or winding" or, in innumerable cases, "bad."[1] It is the *fenced lane* which predominates. The region seems likewise to be cleared of woodland, which occurs to-day only in tiny and isolated enclosures of mixed coniferous and deciduous formation. Thus over the whole region we may visualize from the map a region of farmsteads, hamlets, and villages, linked together by the typical hedgerow-bordered Devonshire lane, the highway of a population which is drawn to the interior rather than to the coast. In spite of the absence of a coastal plain, were the interior inhospitable or unattractive, then the population surely would have become segregated on or near the many little coastal flats which form the seaward termination of each little valley, where actually only diminutive and scattered settlements—presumably of a very few fishermen—are located.

The position of the inland villages provides an interesting study, for the majority lie either at or toward the head of the isolated little valleys leading to Bigbury Bay. The dominant factors which determine their location will be (1) proximity to the zone of maximum attraction and daily occupations, (2) adequate and unpolluted water-supply, (3) ease of village drainage and sanitation (important in such relatively isolated rural districts), (4) proximity to the main highway between external larger centres and to the local routes between adjacent foci. It seems clear that the combination of all these factors has led to the present village grouping, which records the antithesis of coastal attraction. As foci of an agricultural region, in contact with plateau summit, valley side, and valley bottom, yet where an adequate water-supply is guaranteed from the neighbouring stream, their position at the same time avoids the risk of a damp valley bottom or windswept plateau top, and likewise ensures free and natural drainage by utilizing in almost every case the sloping hillside.

But it is in relation to the fourth factor that their position seems to possess especial advantage, for roads of all

[1] Classification of roads (first "Popular" edition).

ses, whether for local or general traffic, distinctly avoid valley bottom. The single main road "fit for fast fic" leads from Kingsbridge to Salcombe, and definitely ows the plateau summit, almost coinciding with the water-ting between streams flowing eastward and westward, hough this route involves a considerable *détour* from the st direct line between the two town centres. But the rse of the road is clearly dependent upon two factors:

1) In the first place, there are no outstanding inter-diate centres which should divert the route in any diffe-t direction from that now followed, whether to become re or less devious. Hence by following the water-parting road lies intermediate between a series of villages lying h to east and west, which, however, by reason of their ition near the plateau summit, can easily communicate h the main highway, to which they are linked individually quite short, indifferent lanes of relatively gentle gradient. ly at two points—the one quite close to Kingsbridge, other near to Salcombe—does this main road pass ough a village. That which lies some 3 miles north-west Salcombe seems to be of quite considerable impor-ce, yet even here it is probable that Malborough has wn round the natural route convergence at the plateau d-fork rather than the road which has deviated to pass ough this centre. It is the largest village of this south-tern peninsula, although occupying a position remote n direct contact with the sea, and its local importance y be measured by the fact that, unlike any other village hamlet, it possesses two churches. In regions of this type topography it is easier to meet on the plateau summit n in any individual isolated valley.

2) Apart from the importance of contact with the scat-ed rural population, there is a second equally fundamental trol. If easy road gradients are to be maintained, then route following the plateau summit is the only one prac-ble. As a result of the dissection of the plateau into rnating coomb and ridge, a more direct route would vitably involve a succession of steep ascents and descents rossing from valley to valley. It pays, therefore, to make

this wide *détour*, so that the very gentle gradients of the plateau summits may be utilized.

It may, however, equally be in relation to local lines as to main lines of communication that an up-valley village site is desirable. The revised "Popular" edition of the Ordnance Survey map proves each east-to-west valley, with its valley village, to possess a measure of local unity as a separate parish. The parish villages are linked together by a north-to-south lane (rather than a road). No matter what route the main road (related to external centres) may have chosen to follow, the local roads seem bound to seek the higher levels. From the north-to-south local road east-to-west lanes branch to the shore-line, and maintain relatively easy gradients by avoiding the valley bottoms. Thus they drop to the west coast either slowly, along the valley wall, or follow the summits between adjacent valleys as 'ridge roads.' It is in relation to this network of local upland roads that the villages may have grown. The advantages of an up-valley position become especially clear when one imagines the conditions which would obtain if each village lay half a mile seaward of its present position, and on the valley bottom rather than the valley side. A site such as this would lead to a very pronounced isolation of each village within what is in some cases quite a narrow and restricted coomb, while the construction of a north-to-south link road or lane between these little agricultural communities would seem almost to be useless, owing to the repeated steep gradients which the crossing of successive ridges would then entail. Thus the village has grown at the first upstream position where greater altitude and proximity to the ridge summit ensure relatively easy contact with its immediate neighbours, to both north and south (although it may be noted that even the lanes have quite steep gradients as compared with those of the main road previously described). In some cases this position is attained midway up the valley, in others not until the valley head is reached. Since we have suggested that the villages are bound to lie near the plateau summit, there must be considerable risk of exposure to high winds. The way in which villages cluster just below the summit is of

interest in this respect, while in greater detail one may notice that many nestle in any small tributary valley, or gully, which provides a sheltered hollow behind the more exposed front of the main valley wall. In the case of the east- and west-facing valleys the placement of the villages behind groups of outcurving contours (*i.e.*, spurs), and in no case at the head of a westward-facing valley, is very significant.

East of the Kingsbridge inlet the fundamental influences seem to be of a similar nature. A conspicuous feature is the general sparsity of population—far fewer villages are present within this region. This may be due to the lesser development of east-to-west valleys as compared with that characterizing Bigbury Bay. But the very small villages and hamlets which do occur in the eastern peninsula again tend to lie in up-valley or plateauward positions, and the importance of the plateau route is here equally apparent. The absence of a centre of attraction such as Salcombe on the eastern side of the inlet is a contributory factor, emphasizing the isolation of this eastern unit; not a single first-class road threads its way southward into this region to compare with the road between Salcombe and Kingsbridge.

This section of the map—*i.e.*, east of the inlet—is again typical of the whole sheet in depicting quite local roads, which trend for many miles scarcely passing a single dwelling. Village or hamlet clusters just below the plateau summit, quite near to, but out of sight of the lane or road. Equally characteristic are the innumerable examples of named cross-roads or cross-lanes (*e.g.*, Cousin's Cross, Dunstone Cross, etc.—see full Ordnance Survey sheet for countless examples), yet these in no case locate habitations, but only road junctions, whose importance as meeting-places is thereby suggested.

In Start Bay the boldly cliffed shore-line is a zone in many cases of less attraction than that of Bigbury Bay. None the less, one may identify the presence of a few very small fishing villages, whose position and form are characteristic of their type. North of Start Point a short, single line of dwellings straggles along the exceedingly narrow front provided

by the raised beach. Here, therefore, the inhabitants dwell in immediate contact not so much with the land as with the sea, yet above the limit of wave action, and, at least in part, beneath the shelter afforded by the old line of sea-cliff which backs the village. The truncated spurs isolate Hallsands village from Beesands similarly placed to the north by a reach of intervening cliff-bordered shore-line. The absence of a coastal road may determine that intercommunication is most easy by sea—the alternative to a circuitous and quite arduous land journey over the intervening ridges. From the map one may visualize the short string of probably ramshackle dwellings beneath the line of brown cliff, facing the stretch of sands or shingle and the sea. We can imagine the watchman climbing to the cliff summit which immediately looks both over the village below and away far out into the bay; we can hear the shout and sudden burst of activity below as he points seaward, directing his fellow-fishermen to the darkened patch of water and the promise of a harvest which a long-trained and observant eye has located. But although fishing activities may be extended southward around and beyond Start Point, there is no trace of settlement on the southern rock-bound shore-line. In the east of the South Devon peninsula, as in the west, it is therefore to the interior that the major interests of the population are related.

Finally, the position of the one school marked on earlier maps (*i.e.*, 1½ miles *south-west* of C) seems to epitomize the whole situation. One naturally expects to find the school somewhere in the chief village, or at least near a centre of population. But here the reverse is the case. The school lies completely isolated—a small, solitary building separated almost by a mile in any direction from the nearest hamlet. But in a region so sparsely populated one school must serve a large area, and therefore is placed to give equal facilities for children from all centres within its range. Therefore it lies almost at the head of a valley, toward the plateau summit, where plateau and valley lanes meet, in close proximity to no one centre, yet providing a journey of roughly equal length and difficulty from any one of the surrounding ham-

lets; it is a medium which links the families of the local fisherman of the coast and of the local farmer of the interior.

The previous discussion has dealt with aspects of local geography, depending upon a detailed study of the map. We may turn in conclusion to consider the position and *rôle* of the two major centres of activity, whose presence probably arrested the map-reader's attention first of all.

Kingsbridge and Salcombe, each possessing a population of less than 10,000, occupy terminal positions at either end of the submerged inlet. The two centres play rather different geographical *rôles*, that of Kingsbridge being of more general importance. Situated at the head of the Kingsbridge estuary, it is obviously a cross-route centre, through which all land routes (particularly from the south-west and south-east) inevitably tend to make a *détour* to avoid the barrier which the estuary presents to cross-peninsula traffic. Kingsbridge therefore most probably stands as the market town of the whole region, since it is a centre to which both local and main road traffic naturally gravitates. Five main roads converge here, four of which are ridge and plateau roads—*i.e.*, those south to Salcombe, north-west to Plymouth, north-east to the agricultural centres of Totnes and Newton Abbot (see full sheet), and north to local agricultural centres. The fifth road leads eastward along a pronounced depression to Slapton Ley, to become a coast road trending north to Dartmouth. From a cross-road nucleus Kingsbridge town has expanded to straggle along each main road, and has therefore an unconsolidated form. The nodality of the site is increased by the presence of a Great Western Railway branch line (single track), which terminates at Kingsbridge. The line (leading from South Brent, 10 miles to the north) must have been constructed with the needs of Kingsbridge market, as the focus of the whole southern peninsula, especially in mind, for the full sheet reveals the presence of no other intervening centre which would justify its construction. That the line is a single-track branch from the main railway, which lies so many miles to the north, is sufficient comment on the local importance of both Kingsbridge and the whole region which it serves. The railway, in following

a restricted valley route, may be contrasted with the general plateau route of the roads.

To the possibilities of communication with Kingsbridge by road and rail that by water should be added. There is some evidence to show that a sea-route between Kingsbridge and Salcombe is possible, for lightship warnings are placed *en route* between the two centres, defining a course which may be practicable at any state of the tide, and, furthermore, the suburb of Kingsbridge which has grown south-eastward along the Slapton road, and which overlooks the creek, is named Newquay, a name suggesting the position of a place of landing. But the extensive tidal flats, restricted channel, and small volume of the river suggest that water-borne traffic may supplement, but could never supplant a greater road transport between the two urban centres. It seems probable that without very extensive dredging operations only boats of very shallow draught could negotiate the channel, which in any case leads to a market centre offering only limited harbourage, and possessing an exceedingly restricted natural hinterland. It is the last factor which probably determines the very local importance of the inlet. The lack of an effective hinterland has meant that no port of any size can arise within this apparently sheltered and extensive inlet, whose traffic therefore remains related to no external overseas or distant inland interests. All factors combine to suggest that Kingsbridge, though at the head of a tidal inlet, is a centre as predominantly related to land rather than sea interests as are the majority of village centres within the whole peninsula to the south.[1]

Salcombe is more immediately in contact with the sea, but is probably of little importance other than as a tourist centre, for which, however, its position and environs must be well adapted. The town seems to have grown up the steep hill slopes which overlook both a branch creek and the sheltered reach of estuary marked as a harbour. But Salcombe can never have become a port of any very considerable value, in spite of the shelter for craft which the

[1] Actually Kingsbridge was more important as a port in historic times but of this there is no evidence on the map.

almost landlocked inlet provides. For in the first place access to the interior from this site is nowhere easy, while the extent of safe harbourage is very limited. Dangers of several kinds impede navigation. There is, for example, a bar marked across the opening of the inlet which probably prohibits the entry of large craft at low tide. Lightship warnings are placed within the inlet, and these, together with many small rock pinnacles and islets, suggest that there are many dangerous reef rocks and shoals to be crossed before reaching the harbour itself. Furthermore, the fact that the ferry across the estuary at Salcombe is marked on the Ordnance Survey map as one for foot-passengers only, and not for vehicles, suggests that the water may at times be exceedingly low.

Salcombe might perhaps function to a small extent as a centre for the fishing industries previously suggested as occurring locally around adjacent coasts. But this seems unlikely, for as a collecting port Salcombe possesses little advantage, since no facilities for quick transport by rail are present. Indeed, the lack of means of communication with the interior (excepting the one plateau road) is alone quite convincing evidence of the purely local importance of the site, for there seems to be little, if any, topographical obstruction to hinder a fairly direct continuation of the railway from Kingsbridge to Salcombe, given sufficient economic demand for its construction.

In former times the town may have had greater importance; at least it is clear that the site was worthy of fortification, presumably against sea invasion, for Fort Charles lies on a rocky islet, commanding the approach to the sheltered harbour behind, and therefore could control the passage of ships to and from Salcombe.

To-day we may view the town as a centre of the tourist industry, which is probably of growing importance around all coasts. As a pleasure resort Salcombe inevitably should have many attractions, not the least of which lies probably in the scenery, associated with bold headlands and submerged uplands. The same tourist value of shore-lines can be traced at intervals along the coast, from the presence of

both golf-links and hotels. The development of this industry is leading—at least locally—to a change in the relative value and degree of economic attraction of shore-line *versus* interior situations.

The sections of shore-line between Start Point and Salcombe (especially Prawle Point to Salcombe), or from Bolt Tail to Bolt Head, remain isolated and quite unrelated to the interior, in which respect they are typical of many coasts whose general direction runs parallel with rather than transversely across the grain of the land. (Compare, therefore, with the coasts of Bigbury and Start Bays.) Not only are there practically no lines of easy access to the interior, but there is literally no trace of coastal plain present, and the innumerable coves and bays into which the coast is fretted have become in no case the sites of fishing villages. The few villages present, though scarcely half a mile distant from the shore-line, are *plateau* villages, and bear no relation to the sea which they overlook, and to which in some cases not even a footpath leads.

The foregoing geographical analysis is incomplete unless the details of the environment are viewed in relation to a broader regional setting. It will be recalled that in relation to South-west England the whole unit forms a peninsula standing far out southward into the English Channel. Had local geographical conditions provided easy access to the interior and a harbour of adequate depth (in keeping with the width of the sheltered bay), even then, as stations on a promontory of land, it is unlikely that either Kingsbridge or Salcombe would have become great trading ports, though they might, alternatively, have risen to some importance as packet stations.

Norwegian Type

Map XXI depicts a region similar to that previously discussed (South Devon) in that it comprises part of a dissected plateau whose shore features have been primarily determined by submergence. But the region differs in some fundamental aspects of its physical history; thus the low and generally softly moulded plateau relief of South Devon is here replaced

by a section of intensely glaciated highland, and therefore the topographic detail and the essential features in the human response contrast very strongly. The student should note carefully the smaller scale and changed contour interval before he attempts to study and interpret this map, which presents a characteristic example of the Norwegian environment. Here the influence of glaciation is closely interrelated in both physical and human associations with two very typical yet contrasting coastal forms—the fjord and the strand-flat. It should be remembered that in many respects a similar physical environment may be identified in the study of many of the Ordnance Survey sheets of Western Scotland.

The recent occurrence of complete continental as opposed to valley glaciation[1] is revealed in the typical fjeld topography of the interior, where a plateau approximately 400–600 metres in altitude is dissected into isolated uplands bounded by steep-sided but broad U-shaped passes and through valleys. Particularly clear is the isolation of the Vetefjeld from the southern Torskvatsfjeld and Middagsfjeld by the markedly broad and continuous furrow which links Kvœfjorden (*i.e.*, the fjord at Vikeland) and Harstad.

A conspicuous feature even at maximum elevations high above the limit of tree-growth is the absence of any indication of precipitous and angular outlines such as characterize higher Alpine ridges (see Maps XIV–XVI). Here the contouring suggests widespread submergence beneath an ice-sheet of a plateau composed of old, resistant rock rather than a region of Alpine configuration and relatively young rocks. It results that only rounded and ice-smoothed surfaces are exposed to-day; plateau and pass remain as areas of extensive marshland or lake-strewn flats, from which at intervals protrude low, but always rounded knolls. The drainage from either the U-valley lakes between the fjelds or from the swift torrents of the fjeld borders assumes an indeterminate direction in traversing the zones of forested marshland to the sea. Particularly is this characteristic of the central through valley behind Harstad.

[1] That is, by an ice-sheet rather than by valley glaciers.

The fjeld upland of the interior is replaced at the coast by equally characteristic land-forms, the fjord and the strand-flat. In so limited a section of the full topographical map there is indicated only a small section of the complete fjord network. Even so, we may identify the essential features of this type of coast in two directions. (1) The densely packed and remarkably straight contours of both the south side of Topsundet and the north side of Kasfjorden give clear evidence of the ice-steepened walls characteristic of this land-form, while the absence of offshore islands or shallow water, together with the actual sea-depths indicated, suggest the continued rapid descent of the fjord walls below the water on both sides of the inlet. (2) The marked parallelism of neighbouring inlets and the rectangular pattern characteristic of the complete fjord network can be traced here by the parallel trend of Kasfjorden, Topsundet, and Kvœfjorden (Vikeland), or by the north-eastern bend of the east coast of Grytöya (north of the fjord of Topsundet). Vaagsfjorden, again, lies at an angle of 45° to either of the previous directions. It is equally noticeable how many of the minor indentations of the east coast repeat the north-east to south-west direction of the strait west of Aaker Island. In the case of Kilbotn inlet (west of the island of Rogla) it is possible to identify by the sea-depths of 144, 160, and 216 metres a submarine depression which continues the same direction.[1]

The presence of a submarine bar or sill breaking the fjord floor cannot be traced in this section of the map, but it may be identified in larger fjord areas. Three kilometres from the head of Kvœfjorden, however, a ridge all but completely isolates Straumsbotn from the main fjord channel below, and thus exemplifies the manner in which sub-aerial thresholds, like the submarine bar, may break the continuity of slope toward deeper water by dividing the inlet into separate basins. It is impossible to suggest from so small a section

[1] The student is especially advised to study 1-inch Ordnance Survey maps of the fjord coasts of Scotland, which (since they show both sea and land contours) are in some respects of greater value in portraying land-forms than the Norwegian 1 : 100,000 map. (See sheets 35, 46, 53, 54, and 60 of the "Popular" 1-inch edition, Scotland.)

of the map whether the ridge in this case represents a barrier of morainic material or whether it marks the boundary between basins which have been differentially eroded and over-deepened by ice or—as others would suggest[1]—which are determined by structural lines of dislocation. Whatever the origin, only a slight submergence would drown the bar to form a submarine ridge, while an even slighter degree of elevation would result in the formation of a lake behind the bar, which would then terminate the inlet. The latter condition is exemplified in the case of Kasfjorden, which ends at a narrow, low bar, beyond which a lake continues the fjord inlet.

The eastern shore-line contrasts markedly with the coast of Topsundet and Kasfjorden, for here there is at least an approximation to a coastal plain, though this is of variable and always narrow width, and tends in general to be relatively rugged, indented, and island-fringed. The width is determined roughly by the position of the 60 metres contour, above which slopes are everywhere relatively steep, rising thus to the fjeld plateaus. Particularly interesting is the form of the two peninsulas to the north and south of Harstad and that of the island of Rogla to the south, for in each case this consists of a relatively broad, low, and flat terrace comparable in form to a rim fused on to a central and distinctly rugged nucleus. Only a slight submergence would result in the breaching of the Harstad peninsulas to become rocky offshore islands. In short, these features, in conjunction with the whole coastal plain, seem very clearly to illustrate the form of a raised wave-cut platform, or strand-flat, which, though not due to direct glaciation, may at least be classed as in part an indirect product of the Ice Age.[2]

That a rocky platform, probably of similar origin, extends beyond the shore-line at no great depth is indicated by the island and shoal fringes and the actual rock pinnacles projecting above sea-level. The presence of all these features on or bordering the east coast causes the latter to differ

[1] See J. W. Gregory, *The Nature and Origin of Fiords.*

[2] See F. Nansen, *Strandflat and Isostasy*, or the summary of theories on the subject in *The Polar Regions*, by R. N. Rudmose Brown, pp. 69–71.

markedly in surface and submarine relief from the northern and western shore-lines previously described.

Human Response. In tracing the nature of the human response even the key to the 1 : 100,000 map is found to be an interesting and suggestive geographical study. It enables the map-reader to see the region from the standpoint of the Norwegian, with correct emphasis on those aspects which he realizes to be the essentials. The key on the original sheet (of which only an incomplete adaptation is included here) gives the usual fairly detailed distinctions in administrative boundaries, a sixfold classification of roads and footpaths (including a separate symbol for paths or snow-tracks used only during the winter season), a fivefold railway classification (including a symbol for the rope railway), and the general distinction between marshland, coniferous and deciduous woods, etc.

The remaining symbols can be divided into three groups. One indicates different industries (saw-mills, factories, etc.). A second, interesting in the direction of the emphasis, includes a series of symbols to denote harbour lights, warnings, positions of submerged rocks, etc., and thus clearly suggests the importance of a detailed knowledge of the sea as a common highway. The third group of symbols is of interest in indicating the character of land settlement. A modified classification on Map XXI is used to show the features which have received special discrimination on the original sheet.

Some symbols show habitations allied in interest to agriculture. The circle represents the *gaard,* or larger farm on the estate of the peasant proprietor. The squares locate smaller farm cottages and associated buildings, in large part probably only for temporary occupation. A feature of no little significance in comparison with the Swiss maps is the definite indication on this map of the habitation used for summer pasturage—*i.e.*, the *saeter*, or summer *chalet* on the fjeld pastures, and shown here by the black dot. From the map it is therefore possible to gain a far more accurate measure of the extent of transhumance.

A black dot also denotes habitations in the main not

related to agricultural interests—*e.g.*, the villa or school and some other types sharing the same symbol. Discrimination between these types of buildings is possible, for the appropriate word is printed beside the dot when this does not represent the villa. In this section of the map schools occur apart from private villas, and the former are distinguished by the word "skole" beside the appropriate dot. Similarly, the black rectangle stands primarily for the fish-stall or boathouse, though additional letters beside the symbol may denote the shooting-box or cattle-station. In this way the possibilities of map-interpretation are considerably extended. Finally, the fact that the original key includes a separate symbol for the indication of telegraph lines and stations is of interest when we recall the importance in these and similar regions of telegraphic intercommunication in minimizing the apparent isolation of scattered and remote farmsteads and even of individual *saeter*, occupied only during the summer season.

Small as is this section of the Harstad sheet, yet it illustrates the essential characteristics of the human response to an environment so largely determined by the dual influence of latitude and, directly or indirectly, of glaciation. In the study of foreign topographical maps it is important to notice the latitude of the region, which in this present case indicates that the district lies within the Arctic Circle and therefore is characterized by the protracted insolation of prolonged summer days and the contrasting gloom—particularly in the fjord inlets—during the equally extended winter nights. The presence of deciduous forests bears testimony to pronounced oceanic influence, resulting in a climate far less rigorous than the high latitude would at first suggest. (Harstad is, in fact, very nearly 69° north.)

An outstanding feature in the distribution of settlement is the marginal concentration along the coasts and the close relation between density of population and the width of the coastal plain. Thus particularly along parts of Topsundet and Kasfjorden settlement is as meagre as are the narrow traces of plain, while where, as along the strand-flat coasts, there is a maximum area of low-lying, if rocky, terrace

there are the densest and most continuous zones of occupation. Equally characteristic are the small foci of settlement on the flats which lie at or near the head of adjacent fjord inlets—*e.g.*, Straumen and Vik and Kasfjord.

That the population is crushed out on to the coast by an inhospitable interior may be illustrated by reference to several features. First we may note the unattractiveness and poverty of the mainland, which are largely determined by the details of the present topography as the product of glaciation; they are also, however, related to the latitude, as reflected in the low limit of tree-growth, here only 400 to 500 metres above sea-level, in contrast to that indicated on the Swiss maps.

The degree to which the population is forced to the coast rather than attracted toward inland expansion over the fjeld is indicated by the immediate utilization of even the smallest coastal flat as it extends outward around the excessively steepened fjord wall, no matter how isolated it may be from adjacent centres (see the farms on the north side of Kasfjorden and the south side of Topsundet). That the *gaards* persist singly or in small groups when so remotely situated and so cut off landward from the main centres of attraction suggests the great value of the sea itself as the primary highway for intercommunication, and one which therefore minimizes the apparent isolation of these separate coastal units. Indeed, the value of the sea-way determines that every farmstead so placed fronts on to a highway probably of far greater importance than any of the roads which may lead inland.

Even more striking testimony as to the attraction of the low-lying coast-lands is seen in the expansion of agriculture out on to the rocky island fringe. Thus even the smallest rocky islet may possess several or even but one *gaard*. One realizes how great, surely, is the poverty of the interior, how meagre the harvest from individual farms, and how isolated and individualistic the farmer who toils under these conditions. The sea, as the highway of primary importance, is paralleled by a land route, which, as would be expected, closely borders the coast-line linking together the scattered

farms and main foci of settlement. But, unlike the sea-way, the coastal highway is bound to be discontinuous, broken (as, too, is the zone of settlement) where reaches of cliff-bordered shore-line prohibit further longshore penetration (*e.g.*, along Kasfjorden and Topsundet).

Routes inland are restricted to the lines of through valleys —features of the greatest importance in providing trans-plateau connexions between neighbouring fjord inlets, and here well exemplified by the roadways which converge to Harstad from Kasfjorden and Straumsbotn. Some interior settlement does occur, but only where relatively close contact with these main highways can be maintained—as, for example, behind Harstad.

That agriculture is of predominant importance in the yearly round of activities might at first glance seem to be suggested by the innumerable *gaards* clustering over the entire region which provides opportunity for successful cultivation—*i.e.*, where there exists the maximum plain at the minimum altitude. As regards the nature of agricultural development, there seems to be definite proof of relatively little transhumance to the fjeld pastures in this region, for, in relation to the *gaards* of the coastal plain, the *saeter* are very much scattered and few in number.[1]

Apart from agriculture, there seems little evidence of the exploitation of the natural resources of the land. Thus there is no trace of hydro-electric development. One mill only is indicated, near the coast at Vikeland. Similarly there is practically no evidence of timber exploitation; forests still clothe the mountain-sides, in many places down to the sea-shore.

The general poverty which crushes the cultivator out on to the offshore islands (and which latitude and relief would seem to explain) suggests the existence of some compen-

[1] The district around Harstad is described in some detail in vol. xix of *Norges Land og Folk: Tromso Amt* ("Kvœfjord og Trondenes Herreder") (Oslo, 1899), pages 63–96, and it is interesting to note that here the unit is said to be one of exceptional fertility, the district being especially favoured by the presence of outcrops of limestones and slates! The unusually large number of *gaards* marked on the map does point to rather exceptionally high fertility.

sating attraction which supplements the deficiencies of the homeland itself. That such does exist seems clear from an examination of the symbolism depicting the two centres of attraction to which settlement is drawn—*i.e.*, the head of Kasfjorden and, more especially, Harstad. In both cases these definitely indicate the establishment of fishing centres. Not only, therefore, may the population be crushed from the interior to the relatively attractive coastal plain, but equally may it be drawn from the inhospitable plateau to a zone in contact with the richer yields of the sea. Thus we come to regard the inhabitants of this region as more probably fisher-farmers, returning seasonally or at shorter intervals from the sea to wring from the soil by intensive labour the meagre gifts of a relatively barren land, whose remoteness and insular isolation are reflected in the lack of any railways or telegraphic communications, which the key indicates to be present in other more favoured localities.

Finally we may consider why the centres of the fishing industry should have arisen at Harstad and, to a much smaller degree, at Kasfjord. It is normal to expect the occurrence of a fishing village at the head of a fjord inlet —*i.e.*, at the first point where an extension of relatively flat land may occur; yet if this factor alone has determined the location of Kasfjord, one wonders why no corresponding fishing village has arisen at the head of Straumsbotn. Again, there are many reasons why a larger centre should be situated on the east rather than the west of Hinnöya Island (on which Harstad stands), not all of them apparent simply from a study of this small section of the full sheet.

Fig. 27 depicts Harstad in relation to the commune of which it is the chief focus. Situated on the east coast, on the leeward side of Hinnöya Island, and at the same time on the margin of the only plain, the town occupies a position which is both sheltered and within the only zone of dense settlement and agricultural opportunity. When Harstad is considered in relation to the commune bounds, additional and still more important advantages of site become obvious. It occupies a central position at the junction of sea-roads. If the commune boundary delimits a sphere of local interests,

then it is of no little significance that the boundary bisects four of the larger islands.[1] The land units, both islands and

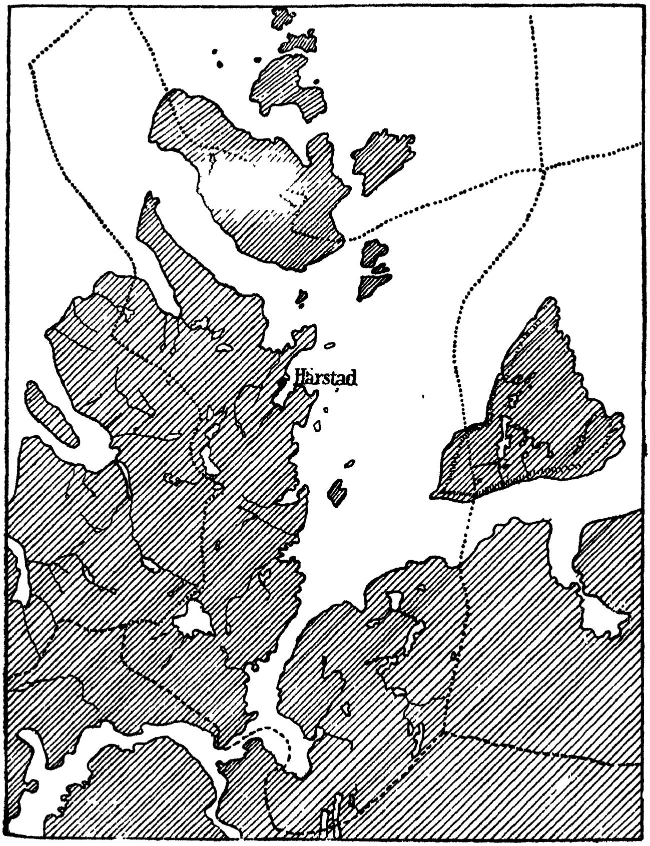


FIG. 27. MAP TO SHOW THE EXTENT OF THE COMMUNE OF HARSTAD

Scale approximately 10 miles to the inch.

peninsulas, are crossed and broken up by the commune boundaries, because the human units are concerned with the sea rather than the land. This is a complete reversal of

[1] I am indebted to Professor W. Werenskiold, of Oslo, for pointing this out.

the more normal arrangement, in which boundaries enclose land-masses as entities, and run through water-masses as natural boundary zones. Here the sea, a continuous unit, is the focus for the discontinuous settlements which occur along the land margins, and the land, which repels settlement to its borders, is everywhere a boundary zone.

What are the factors, however, which have determined a location at Harstad rather than at any other position along the east coast? The town may have grown at this position because of the presence of the two peninsulas to north and south of Harstad Bay, within whose arms there is relative shelter and safe anchorage, while landward there is easy through-valley connexion with both Kasfjorden and Straumsbotn, to the north-west and south-west. But alone these cannot have been the determining factors, for immediately to the north of the Trondenes peninsula there lies a bay equally protected by land promontories on either hand, and similarly placed at the junction of sea-ways. Moreover, landward this second bay is yet more favourably placed, owing to the direct and easy transit *via* the through-valley roads to both west and south. These converge on this latter bay rather than on Harstad, which is separated from them by quite a distinct, though low divide. Harstad cannot therefore have arisen simply in relation to ease of communication with the interior. The location of both centres, Kasfjord, the fishing village, and Harstad, the fishing port, can only be explained fully by reference to one other symbol not yet noted—namely, the dotted shading which borders part of the shore-line. The key to the map indicates that this refers to shore-lines where accumulations of loose beach material are present—*i.e.*, where, in contrast either to a complete absence of gentle terrace (as along the fjord walls) or to a rocky wave-cut platform bare of shingle deposits (as along many parts of the indented strand-flat coast), there is an adequate reach where boats may be safely and easily landed. We can now understand the location of the fishing station within Kasfjorden (possessing a beach) rather than at the head of Straumsbotn, where apparently practically no trace of beach occurs. Harstad similarly has grown as the lead-

ing centre within the only large bay along the east coast capable of taking a considerable fishing fleet and whose shore is to a marked degree bordered by beach accumulations, contrasting in this respect with most other parts of the east shore-line.

It may, then, be for this reason that the beachless bay to the north (to which the through valley roads converge) has been neglected in favour of Harstad Bay. One wonders why this difference in the nature of the foreshore of these adjacent inlets exists. The map suggests a possible explanation. Offshore both bays sink fairly rapidly to relatively deep water, in the case of Harstad Bay to 145 metres and of the adjacent northern bay to 173 metres. But passing farther seaward there occurs a partially submerged bar (represented by shoals, islands, and shallow water), approximately in line with the termini of the two Harstad peninsulas, and necessitating the presence of warning signals and lights at points of entry to the Harstad harbour from both north-east and south-east (see shoals marked). It may thus happen that the island and reef fringe, which is absent in the adjacent bay, causes either a diminished wave force or a diversion of longshore currents and drift of beach material, so that accumulation occurs to a marked degree around the Harstad shores.

In conclusion, therefore, the factors which have ultimately determined the site of the main focus themselves denote the interests of the region. For Harstad, the one large city, the one centre possessing a church, seems dependent for its importance not simply upon proximity to more favoured agricultural regions, but primarily upon the nodality of sea rather than land route convergences, combined with the needs of the fisherman. Here, as in Norway generally, therefore, it is most likely that the fundamental attraction lies in the unrestricted harvest of the sea, to which as of subsidiary importance may be linked the restricted harvest of the land.

The two coastal regions discussed in this chapter resemble each other physically in that both are partially submerged

uplands, but the human responses of the two regions afford a striking contrast. In the Kingsbridge district the coast marks the border where useful land ends at a relatively useless sea. In the Harstad district it is at the shore-line that a relatively useless land meets a useful sea.

CHAPTER XI

STUDIES OF COASTAL TYPES—PART II

In the present chapter it remains for us to consider the identification of land-forms and the associated human response in coastal regions where there has occurred (*a*) submergence of regions of low relief, (*b*) deposition and reclamation rather than erosion of the land. Again the coast-lands will be considered in relation to the interior, both from the physical and human standpoint.

Submergence of Low Relief

Physical Considerations.[1] The area depicted on Map XXII may be divided clearly into two physiographical provinces. (1) To the south the Isle of Purbeck forms a region as a whole of moderately resistant rocks, for it is associated with quite bold and high relief in the interior, while the coastal margin—in large measure cliff-bordered—is characterized by bold headlands and promontories, giving further indication of the occurrence of rocks which resist marine erosion to a considerable extent. (2) The northern unit comprises a region of contrasting low and subdued topography, for here a plain of almost featureless relief rises scarcely to 100 feet above sea-level. This broad vale forms the lower basin of the Frome and Piddle rivers (draining to Wareham Channel).

The rocks present within these two physical regions seem to be of very different types; moreover, particularly in the case of the Isle of Purbeck, it is possible to identify important local variations within the one unit.

From the headland known as the Foreland (east of Studland) a prominent ridge trends westward, rising to a height

[1] Students should also refer to the Ordnance Survey publication, *Dissected Folds—Ridge and Trough Lands: South England* ("Geographical Types," Series 1: "Land Forms").

in general of between 300 and 600 feet above sea-level. That the ridge consists of chalk is attested by evidence very similar to that deduced from Map III (Chichester). There is an absence of surface drainage, of woodland, farmland, or settlement; and in addition to this negative evidence may be noted the frequency of dry valleys, tumuli, earthworks, and barrows, and the word 'Down' in local ridge names.

To the south, and ranging in width from 2 miles in the east to not more than 1 in the west, is a zone of softer, and on the whole impervious beds, indicated by lower relief, superficial drainage, and considerable farming and settlement. In general physical form and the human response it is reminiscent of the Wealden beds which lie to the north of the South Down escarpment (see Map III). Farther south one passes to a broader zone rising fairly gently from an altitude of under 200 feet to a plateau surface averaging 400 to 500 feet, within which the same criteria lead one to suspect again that higher relief coincides with a second outcrop of limestone. One may note, however, the lesser degree of general plateau dissection, and the many stone quarries present here, yet absent in the chalk belt to the north; while the spurs and embayments characteristic of the latter are now replaced by more regular slopes, as suggested by the longer stretches of straight, parallel contours. These minor contrasts, together with the definite naming of the Purbeck stone quarries, should render possible the identification of the Purbeck limestone of Jurassic age, which the student may have suspected to be present when recalling to mind the general geology of the region. It is probable, however, that if he were not aware that the name 'Purbeck' is given to a certain Jurassic limestone he would be unable to differentiate between this and the chalk as shown on the present map.

Farther to the south the plateau falls by an abrupt escarpment to a coastal plain of variable width, but general low relief. That the plain marks the position of outcrops of an impervious nature seems evident from the presence of surface drainage, while the actual rock formation is amply demonstrated by the frequency of the name 'Kimmeridge,' used for village, farm, bay, and wave-cut foreshore on the

original map. The northward recession of the Purbeck limestone escarpment is therefore steadily exposing a larger extent of the underlying older Kimmeridge clay. From the form of the Jurassic limestone plateau and also the eastern section of the chalk ridge to the north the structure of the region can be viewed as comprising a sequence of rock types, oldest in the south, and differentially eroded into alternate ridge and vale. Though there is some contrast in the gradient of the Jurassic limestone escarpment and dip slope, yet in the north there is rather less difference between the north and south slope of the Down ridge, which may be due to a great increase in the dip of the beds in this locality. (For confirmation of the fact see sheets 342 and 343 of the Geological Survey. See also footnote at p. 221.)

It is interesting to notice how the drainage of this small region epitomizes the development of a consequent system. As a result of the northerly dip slope, a consequent has cut a water-gap through the chalk ridge at Corfe Castle, directly comparable in mode of formation—though of such diminutive size—with the gaps in the Downs of the Weald. Similarly, along the softer Wealden beds to the south very pronounced subsequent rivers combine to develop a characteristic trellis pattern. The wind-gap two miles south-west of Studland marks the former position of a consequent whose beheaded course may probably be traced flowing north to join the estuary of the Frome.

The nature of marine denudation can be readily gauged once these structural features have been identified. Viewed from the full Ordnance Survey sheet in relation to the shoreline of South England, the whole of the southern physical unit is seen to extend as a bold promontory to St Alban's Head. The sea around the Isle of Purbeck is primarily concerned with erosion, associated with the recession of headlands—hence the prevalence of cliffs immediately along the shore-line for many miles, and the rock pinnacles (marked on the full Ordnance Survey sheet), which clearly are broken relics of the receding mainland. Again, in many cases the shore is bordered by a wave-cut terrace rather than beach accumulations, while a steepened offshore gradient is indicated

by the closeness of the submarine contours (at 5 fathom intervals). It is of interest in this connexion to compare the distance of the 5 fathom line from the coast of Poole Harbour with that in the neighbourhood of Swanage Bay and St Alban's Head, to the south.

The southern and south-eastern shore-lines are not concordant. Bays of varying size alternate with very conspicuous headlands. Particularly pronounced are Worbarrow and Swanage Bays, which, though perhaps partly resulting from submergence, at least in some measure are indentations cut out by marine erosion, for both are almost entirely cliff-bordered. This shore-line seems to afford an illustration of the importance of differential erosion by the sea along outcrops of softer rocks where these extend to the coast, for headlands occur only where belts of higher interior relief run out to the coast, while the bays coincide in orientation, width, and position with the vale—presumably of softer rock—that lies between the two limestone ridges. The contrast in the trends of Worbarrow Bay (from west to east) and Swanage Bay (from north to south) is very clearly related to the narrowing of the outcrop and the slight change in the direction of the graining of the peninsula.

The softer Kimmeridge clay has been identified south of the curved Jurassic escarpment, between E and G. The escarpment has receded farthest in the neighbourhood of Kimmeridge village, and it is interesting to notice how the sea has likewise encroached farthest inland at a corresponding position along the coast. The partially submerged valley of the stream which has cut back into the escarpment must have given a start to the marine excavation of Kimmeridge Bay.

The second and contrasting physiographical province includes the area to the north of the Isle of Purbeck. The whole comprises a broad vale of very slight relief, diversified almost solely by the valleys of the Frome and Piddle. Above Wareham these two rivers flow in separate valleys, each of which is of very mature form, the two being divided by a relatively low ridge tapering eastward. Below Wareham the rivers unite, and flow across a broad and flat plain to enter

a remarkably wide estuary, broken by low peninsulas and islands of ragged outline and wide extensions of tidal flats.

To north and south the land rises, in no case to an altitude exceeding 200 feet (the bulk of the region lies below 50 feet). With this topography may be associated the widespread occurrence of coniferous woods, abundance of heath, more locally clay pits and pottery works, and, in general, a sparsity of farms. Surface features, vegetation, and occupations therefore are all consistent with the surmise that just as the rocks of Purbeck comprise outcrops of successively younger formations dipping northward (as one passes from south to north), so north of the Purbeck dip slope deposits of Tertiary beds overlie the chalk in a sequence of clays and sands, with perhaps local deposits of plateau gravels. The Frome-Piddle system, trending from west to east, lies therefore parallel to the strike of the rocks, to determine that the predominant line of drainage within the whole larger region is subsequent in direction.

Of considerable physical and human interest is the large estuary which the united rivers enter. At high tide, when all the region which on the map is covered by stippling becomes submerged, a vast and almost landlocked bay extends for 5 miles inland. At its maximum north-to-south extension the 'lake' will exceed 4 miles in width, for Holes Bay, behind Poole, continues for a full mile north of the limits shown on this map. At low tide a correspondingly large area of mud flats will be exposed, penetrating deeply into the interior. Each tidal creek around the bay is drained at low tide by a channel which is continuous with a tributary leading from surrounding slopes. In short, the region exemplifies (as in the case of Map XX) a shore-line of submergence. The greater size of the Poole inlet as contrasted with that at Kingsbridge is not necessarily due to greater earth-movements, resulting in more extensive submergence; rather is it due to the different character of the valleys which are submerged. Thus the dissected plateau of somewhat bolder relief and more youthful form produces the ria (or, it may be, the fjord) type of inlet, while the submergence of the present region, comprising broad and flat valleys

characteristic of a region in the stage of late maturity, has resulted in the formation of a broad, open estuary.

The low island of Brownsea—which is quite extensively wooded with coniferous trees, as is the mainland to the south—very probably represents the unsubmerged summit of a divide once continuous, though low in altitude, which separated the adjacent tributary valleys. The tiny islands to the south probably mark the trend of the unsubmerged ridge. A similar origin may explain the occurrence of other small islands within the bay, but in some cases it is more probable that they have grown by deposition and the reclamation of sand- or mud-banks.

Estuaries in general are funnel-shaped, opening more and more widely as the sea is approached. Poole Harbour is remarkable in that this broad bay narrows so that at its eastern side the entry to the sea is no wider than the actual river-channel. Indeed, the latter seems unnaturally constricted, for 1 mile to the north of the harbour entry the channel is much wider. The map depicts an interesting phase not uncommon in the history of submerged coasts, for the constriction to form an all but landlocked bay is due to modifications effected by processes of marine *deposition*, in which respect the shore-line contrasts with the cliff-bordered and marine-eroded south-eastern and southern coasts shown on this map. Beaches rather than cliffs now border two low, flat spits, which, particularly in one instance, seem to have grown by longshore drift of marine-borne material.

From a base on the mainland both spit A to the north and spit B to the south may have grown successively longer and longer athwart what was originally an open bay. Only the flow of the river at right angles to the line of spit growth prevents the complete fusion of these deposits to form a bay bar cutting off the inlet completely and thus forming an inland freshwater lake. Were the rivers which enter the bay of smaller volume, then the present form and history of the bay might have been very different, for the course between the growing spits would probably then have been blocked.

It is probable, however, that, quite apart from the action of the river, the tidal scour through so narrow an opening

will tend to dissipate any further ridge-building as soon as it occurs. The work of finally closing a lagoon by marine deposition is always a most difficult task, and therefore one which frequently remains unaccomplished.

The growth of the northern spit may have affected the trend of the river near its exit from the bay. The Frome flows eastward to within a mile of the spits, where it is deflected southward for a mile and a half. This may be due to the steady growth of the spit across its path, so that the main channel has been pushed progressively farther and farther to the south. The shape of the spit is typical of the land-form. It extends from the northern coast—the base at which the deposit originated—as a very narrow neck of land, at first of low altitude (under 5 feet, according to the spot heights). So attenuated does it appear to be that it would seem possible for a breach to be effected readily during high seas. Farther south, however, it grows in width and altitude, to exceed 50 feet locally. That material is being added to the ridge on its outer margin by sea and wind action seems probable in view of the sand-banks present along the length of the spit. Especially interesting is the club-head form of the spit end, and likewise the tendency which it exhibits to turn inland near its extremity. These are features in which it resembles in miniature—and probably for the same reasons—the curved spit forming Spurn Head. For the Humber, like the Frome, is deflected by spit growth to flow southward. In both cases the river meets a longshore drift from north to south (assuming in the present case that the direction of the spit correctly indicates the line of longshore shingle and sand movement). These features combine with the influence of tidal flow up the estuary to cause the deposition of material at a point progressively farther upstream. As in the case of Spurn Head, it seems reasonable to suggest that material here too is swept round into the harbour, to be deposited on the leeward side of the spit, thus increasing its area in a lateral direction, and compensating for the check in southward growth which may now exist.

The presence of two spits, each pointing toward the centre

of the bay, suggests the occurrence of longshore drift in opposing directions, as an eddy within the bay. Though it is possible for this to occur (it is, indeed, probably the correct explanation of the origin of the bay barriers in this instance[1]), it is unwise to assume simply from the evidence of one map that this must inevitably be the case where narrow, flat tongues of land extend from both sides of a bay margin. We may note, however, that the spit which from its form gives most convincing evidence of longshore drift—*i.e.*, the northern spit, which has grown from north to south—indicates a longshore movement in the reverse direction to that which characterizes the English Channel in general.

The origin of the spit-like growth B seems less certain from map evidence alone. There is no development of a club-head, incurved as in the case of spit A; rather does it end in a very broad, blunt base maintaining the width of the whole spit deposit. (The present map is based on the revised "New Popular Edition" of the Ordnance Survey. In some respects details of spit formation are rather more clearly shown on older O.S. maps.) Westward of the road which bisects the spit coniferous trees and heath are indicated, which, together with the ragged inner margin of part of this feature, suggest that the whole bar may not have been formed by marine deposition, but that the inner section may comprise part of the unsubmerged basin. The coast-line inside the spit continues round the submerged valley of a small northward-flowing tributary, and the inner part of the southern spit may therefore simply represent the normal rise on the east side of this little valley.

Spits, like bars, in some cases recede landward, while at the same time growing in length. Cases where this process can be identified on the topographical map will be discussed

[1] Mr D. Baden-Powell, B.Sc., M.A. (University Museum, Oxford), who has undertaken research on this question, kindly informs me that the drift in reverse directions does seem to occur—*i.e.*, from south to north along spit B and from north to south along spit A. The latter direction of drift may be due to a back-eddy from currents passing around St Alban's Head northward to Hengistbury Head, whence they divide, part recurving westward to spit A.

later in this chapter,[1] but in the present instance there seems evidence to suggest that the alternative process is taking place—*i.e.*, that deposition is proceeding on the outer side, so that the spit is growing seaward, not receding landward. A study of old charts of Poole Harbour lends support to this view.[2] Though the point is beyond the strict bounds of map-interpretation (and therefore of the present subject), it is interesting to note the coastal evolution which these old surveys portray, especially as they show how, in relation to some coastal types, the record of the topographical map should be viewed as depicting transitory rather than stable features.

The survey of 1785 depicts as an indentation of the actual shore-line what is to-day the inner margin of the larger inland lagoon, but by the time of the 1849 survey this inlet has been cut off from direct contact with the sea by the growth of an outer spit, which recurves into Poole Harbour. The lagoons are connected with the sea at high tide by a current which follows the narrow depression trending northward between the inner and outer spits. In 1869 an embankment seems to have been in process of construction, built out eastward from the outer spit. The end of this is actually marked on the topographical map at *e*. This is of especial interest in indicating the importance of artificial structures in modifying coastal topography, for by the time of the 1879 survey the whole of the southern spit shows evidence of having undergone a rapid change. The former depression between the inner and outer spit has been all but filled; there remains only the line of marsh and lake which the topographical map still shows to perpetuate its former direction. Seaward a very rapid growth of sand accumulations as a wedge behind the embankment accounts for

[1] See text-books on the subject of their formation. The reader should consult the standard text-book, D. W. Johnson's *Shore Processes and Shore Line Development*, for details of shore-forms and maps illustrating all types of coastal features.

[2] I am indebted to Rear-Admiral H. P. Douglas, C.M.G. (Hydrographer), and Commander P. S. E. Maxwell, R.N. (Superintendent of Charts), for affording me an opportunity of inspecting old charts of this locality in the Admiralty collection.

the abnormally protruding spit form, now so distinctly out of alignment with the northern spit. It is obvious that from the topographical map alone, beyond the identification of lagoon, marsh belt, and coastal sands, little explanation can be offered without previous knowledge of the facts of the case.

At least, however, it may be noted how eminently favourable for the rapid accumulation of shore deposits and bar formation is this locality, for the southern half of the bay lies in a sheltered position behind the bold promontory of the Foreland, so that deposition can proceed apace, unchecked by erosion. Even more important is the presence in this region of a very gently sloping continental shelf, and therefore an extension of shallow water some long distance from the shore-line. We may contrast this with the steeper submarine gradients and associated evidence of sea erosion along the south coast. Off Poole Bay wave-strength as a purely erosive force must normally be almost spent long before reaching the actual coast.

Human Response. As might be expected, the physical differences between the two regions are sufficient to produce decided contrasts in the human response evoked by proximity to the sea. The Isle of Purbeck is in many respects reminiscent of South Devon. It is natural that the plateau villages (*e.g.*, Matravers) in the south of the region will be linked northward to the main highways and route centres *via* Corfe Castle rather than southward to the isolated shoreline, which is in such very large measure a forbidding and relatively barren coast. But the same lack of close contact with the sea applies to sites on the more favoured Kimmeridge plain of the south-west, which, though a region of restricted area, is at the same time one of relative fertility.

Kimmeridge village, the nucleus of settlement for this very small natural region, though occupying a position scarcely a mile from the sea, lies as far inland as possible, and on a site best likened to that of the spring line villages along the Wealden escarpments. This seems to be the outcome of two primary geographical influences. (1) In relation to internal interests, within this small unit—isolated eastward

and westward by inhospitable shore-lines—the sparse farming population is allied most closely to, and seeks contact with, the denser agricultural population of the vale inland. (2) Considered in relation to external foci and the larger geographical provinces of the Purbeck and Poole district, Kimmeridge plain is a region of almost no significance. No pronounced breach of the escarpment provides access to a coast-line which, in view of the unattractive nature of the shore-line to both east and west, might have possessed possibilities as a coastal outlet for remoter centres. (Compare in this respect the hinterland of Swanage in relation to Poole, Corfe Castle, etc.) These dual influences may therefore have played some part in determining the fact that Kimmeridge village remains small and unimportant, linked with the shore by a winding, unfenced lane of gentle gradient, while a metalled road maintains contact with the interior, even though this necessitates a steep climb over the escarpment.

There is little need to dwell at length on the human geography of the remaining Purbeck district, since here features typical of Wealden geography are paralleled, though on a somewhat diminutive scale. Thus there exists the central belt of farmland and scattered rural population, flanked by Downland and limestone uplands of sparse settlement. Corfe Castle compares with Arundel (Map III); or, if the reader has access to Ordnance Survey sheets of the North Weald, a closer comparison with the site of Guildford might be drawn, illustrating the strategic value of water-gap sites. In this instance a position of particular advantage is obtained, because the Downs are breached by two small rivers, which, uniting immediately to the north of the ridge, have isolated between their valleys a small heart-shaped knoll. As one would expect in the presence of such obvious strategic advantages, the site is crowned by a castle. That in medieval times this site possessed great importance as a military centre is suggested by the fact that the adjacent village gains its name—Corfe Castle—from the stronghold, which obviously could dominate the whole region in commanding the only low breach of the ridge and the line of communication from

Wareham and Poole to Swanage—a direction from which there may have been the menace of sea invasion. But although Corfe Castle lies midway on the main route between Wareham and Swanage, and commands the most clearly defined line of approach through the Purbeck ridge to either of these centres, yet it can be outflanked, for there is a very pronounced wind-gap not 4 miles to the east. Rather is it a centre from which to control the Isle of Purbeck alone, in contrast to Wareham (to be studied later), which dominates a far larger area.

Swanage is the only centre within the Purbeck district with clear maritime interests. These are due doubtless to its sheltered position in the south-western corner of the naturally protected Bay of Swanage, together with easy lines of ingress and the possession of an effective local hinterland which a position at the seaward end of the 'Wealden' vale ensures. Furthermore, since the town lies to leeward of Peveril Point headland, and in a sweep of bay apparently devoid of offshore rocks, the site may possess safe harbourage well protected from westerly and south-westerly gales. How far this may imply that the present resort has grown around a former small fishing village it is not possible to suggest. The shelter of the bay would doubtless be of inestimable value for fishing fleets, while the actual site is additionally favoured by the fact that a small valley here runs out to the sea, to provide a coastal flat around which the town has expanded to both north and south. The heart of this centre therefore occupies the one section of the bay which is not cliff-bordered.

As a tourist centre—of which the town-planning gives evidence, particularly clearly seen on the "Popular" edition—the town will possess many attractions from the point of view of scenery. Thus the panorama of land and bay to be viewed from Durlston Head has been rendered easy of access from the town by the construction of roads and walks above the cliff-face.

Unlike some sites in Poole Bay, to the north (to be considered shortly), there is little direct evidence of past or present importance as a seaport, a fact not surprising in

view of the absence of any outstanding geographical advantages to encourage the growth of any considerable maritime traffic. Yet the site may offer opportunities for the export of one local product. On the plateau behind the town there are many indications of extensive stone-quarrying, presumably for the famous Purbeck stone, the working of which may explain both the location of villages and also the construction of a first-class road along the flanks of the plateau. It seems probable that in the export of so bulky and heavy a commodity the short land route to the coast, involving shipment at Swanage, would be preferable to the much longer, circuitous, and expensive transport overland to Poole, the nearest seaport and railway junction.

It may here be remarked how the single-line railway illustrates the purely local importance of the whole Purbeck unit, a physical entity which, from the point of view of human geography, is less inappropriately named than the configuration at first suggests. In many respects it may in truth be regarded as an 'Isle,' whose individuality is determined (1) by the sea, isolating it to the south and east, and (2) by the broad zone of unattractive and uninhabited heath, together with the tidal flats of Poole Bay, isolating it to the north.

Whereas in the southern region settlement is mainly scattered to form a rural population of varying density and one but little affected by proximity to the sea, in the northern unit population is strongly localized to form the two urban centres of Wareham and Poole, intimately connected with the sea in both the past and the present. This concentration is dependent partly upon the unattractiveness of the region in general, tending to repel settlement from very considerable areas, and partly upon exceptional advantages which the two sites offer for urban development.

Northward from the Purbeck Downs one passes rapidly into a region which seems entirely unsuited to agriculture. A line of farms and small villages thinly borders the immediate foot of the Downs; this may indicate the occurrence of a narrow outcrop of soils contrasting with those farther to the north, which seem to consist chiefly of poor siliceous types

characterized by heath and thin coniferous tree-growth alone. The same conditions seem to obtain for some distance north of the harbour, until, about 5 miles north of Wareham and Poole (see full Ordnance Survey sheet or Fig. 28), heath and sparse farming are again replaced by Downland associations. Though so poor from an agricultural standpoint, the region around Poole Bay seems to possess one economic asset—the clay outcrops, worked locally (see clay works

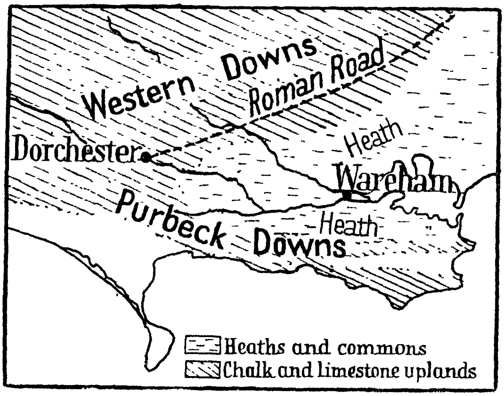


FIG. 28. SKETCH MAP TO SHOW THE RELATION OF WAREHAM TO ADJACENT REGIONS

marked on earlier Ordnance Survey maps). These probably provide the basis for the several potteries indicated, particularly in the vicinity of the towns of Wareham and Poole. Mineral lines, which may transport the clay, run from works situated near the foot of the Purbeck Hills northward on the one hand to wharves near Wareham, and north-eastward on the other to a pier south of Brownsea Island, whence shipment to Poole is probably a relatively easy matter.

Wareham contains at present under 10,000 inhabitants; Poole, on the other hand, is a much larger town, of between 30,000 and 100,000 occupants (according to estimates deduced from the style of print employed on the O.S. sheets up to 1930). There seems evidence, however, to support the suggestion that the relative importance of these centres

has not always been the same. Wareham especially provides an interesting study of a town greatly decayed in value. The map-reader's attention is held at once by the almost quadrilateral shape of the town and by the regular town-planning which is revealed in the interior (see sketch map, Fig. 29). Cross-roads from the four cardinal points intersect practically at right angles in the heart of the site, while from these subsidiary branch roads maintain a gridiron pattern which is strongly reminiscent of Roman town-planning. It is impossible, however, to find any evidence which would definitely connote Roman influence. There are, for example, no Roman roads—whether used or disused—focusing toward this centre. The direction of a section of the great western Roman road through Dorchester can, however, be traced on the full sheet, following a route which, though outside the limits of the present district, may be noted as one skirting the heath margins to maintain a course bordering the Downs. The direct trend of the road, from south-west to north-east some distance north of Wareham, shows traces of neither deviation nor apparently a branch link-road toward the latter town.

The map shows that Wareham is surrounded on three sides by walls. These are indicated by a short hachure which suggests an earth rampart rather than Roman masonry capable of supporting a road. From the type of print employed on the Ordnance Survey map it is possible to identify the walls definitely as non-Roman—they may be of any other construction during ancient British or medieval times. In addition Wareham has been fortified by a castle, the site of which is marked to the south of the town ("Fully Coloured" map). In view of these extensive fortifications this centre may be described as a stronghold of medieval or, it may be, much earlier date, probably at one period of far-reaching importance; its form, together with the fortifications, resembles closely, if not exactly, the bastide type of city. This refers to a form of French medieval town-planning which spread to England toward the close of the thirteenth century. Towns of this type were walled, strongly fortified, and built according to a rectilinear gridiron pattern.

These facts show how unwise it may be to assume to be of Roman origin every town which exhibits a similar form.[1]

The advantages which led to the growth of this centre were two. In the first place, there is a natural convergence of land routes, particularly exemplified by the inter-valley ridge roads—*e.g.*, from the west between the Frome and Piddle valleys—and by the roads from the north-east and north-west, the former skirting the heath margins. The roads from the west even to-day avoid the valley flood-plains—doubtless in former times regions of yet more repellent forest and undrained marshland. But to the east the very large Frome estuary is of great importance. Firstly, it causes routes between the south-east and north-east to make *détours via* Wareham around the head of the bay (*e.g.*, roads between Swanage and Poole). Secondly, its very existence provides a water-highway which, as a sea approach from the east, fills the last sector of the web of routes converging by land from all other quarters.

The long estuary provides a natural highway whereby to penetrate deeply inland, so that Wareham, near the head of the bay, doubtless grew at an early date to function in time of peace as a port, where land trader met sea trader, and in time of war as a vital stronghold in which the land defender could hold a key position against the aggressor from the sea.

In early history the military *rôle* of the centre seems to have predominated, for the walls, castle, and very location speak of a constant need for defence. But as a port the site may have had a long past, perhaps even dating far back into prehistoric times. Owing to the relative lack of attraction of almost all the lower Frome basin at the present time, not only are many traces of prehistoric settlement clearly preserved, but the geographical setting also can be the more clearly visualized, to a degree rather unusual in a coastal region of such low configuration. One wonders how far the seemingly natural vegetation of thin woodland and heath is

[1] With reference to this subject students should consult two historical essays: T. F. Tout, *Medieval Town-planning*, and F. Haverfield, *Studies in Roman Town-planning*.

of primeval origin, or but slightly interfered with by man. As one traverses to-day mile after mile of barren and almost unoccupied country, does the region present a picture similar to that seen by early man? In previous chapters it has been shown how prehistoric man found in drier, lightly wooded, and treeless uplands favourable zones for settlement. This is again clear from the Downs of the Purbeck district, where along the entire length of the ridge are found tumuli, earthworks, and camps, which, together with barrows, are separately indicated on this map. (It should be remembered, however, that in some cases the barrow may not be of such remote antiquity, since, for example, during the Danish invasion and occupation not only were old cairns reopened and utilized, but also new burial mounds were created; these, though of much later formation, are not clearly differentiated on the map.)

There is evidence of comparatively little settlement on the Jurassic limestone as compared with that on the Downland ridge, a fact which suggests a geographical control of an economic nature in prehistoric time. For the Jurassic limestone is neither metal-bearing (like the Carboniferous limestone) nor flint-bearing (like the chalk of the Purbeck Downs), and hence may have offered far less attraction to primitive occupants.

Considering from the distribution of antiquities the evidence of occupation in relation to Wareham's prehistoric or early historic trading value, we may identify belts of archæological remains converging toward the lower Frome-Piddle valley. Not only are these relics relatively thickly distributed along the Down ridge branching north-west *via* Corfe Castle toward Wareham, but a considerable number lie in a broad zone which trends from Worbarrow Bay north-eastward toward the very same centre. Again, equally clear, especially on the full Ordnance Survey sheet, are the lines of antiquities which trend along the crest of the ridge between the Frome and Piddle valleys, and again also along the ridge north of the Piddle, leading in a direction from the north-west toward Wareham. It is noticeable how many of the present main roads trend near to or through these belts,

which, it may be, mark zones of settlement or movement of early peoples. The significance becomes greater when a correlation with hypothetical lines of trade is attempted. In relation to Bronze Age settlement, for example, the district of Wareham may have provided an ideal trading base, long antedating the growth and erection of the medieval centre, which is perpetuated to-day. At this remote period extensive import of metals (perhaps from Brittany and the south-western peninsula) passed *via* the ports which controlled routes leading near to or through zones of dense settlement. The prehistoric port was likely to grow up at a position as far inland as possible, so that the difficulties of heavy land transport were avoided, or minimized, though the sea route might necessitate a lengthened journey.[1]

The map-reader is tempted to visualize in the district of Wareham the growth of a prehistoric port for this Channel metal traffic, the advantages fostering which may be summarized briefly:

(1) The lengthened sea route, replacing the arduous land route, is provided by the long indentation of Poole Bay.

(2) At the head of the bay—*i.e.*, at Wareham—the longer sea route was joined by a short overland route. If it is assumed that traders passed up the Channel and thence rounded St Alban's Head toward the entrance of Poole Harbour, it seems not unlikely that this part of the sea journey may have been beset with many dangers, resulting from the exposed nature of the coast and the liability to storms—unquestionably a great menace to primitive craft. If the coast-line has remained but slightly altered in character (though perhaps not in position) since those bygone times, then once the early craft had passed east of Worbarrow Bay the shore-line must have been such as would afford practically no opportunity for landing—still less of easy penetration inland—until St Alban's Head had been rounded and either Swanage Bay or Poole Bay had been reached.

Worbarrow Bay, however, lies just in a breach of the Downlands, which rise fairly boldly in the South Dorset

[1] See O. G. S. Crawford, "Prehistoric Geography," in the *Geographical Review*, vol. xiii, 1922, pp. 257–263.

Downs to the west and Purbeck Downs to the east. Viewed on the full Ordnance Survey sheet, the breach in the configuration is very clear. The bay itself is cliff-bordered except in one narrow zone, where a low pass leads directly back into the low plains toward Wareham; it is therefore all the more significant that this suggested short overland cut is followed by a chain of archæological remains, which begins at this pass through the back of the bay. The curve of the Dorset coast-line determines the fact that this land route provides the shortest overland link with the English Channel; moreover, the route passes *via* open heath between the suggested dense settlements on the Downs to both west and east. This fact brings us to the third and last influence favouring the surmise that a prehistoric port might have existed near Wareham.

(3) The port would have required an effective hinterland.[1] It is easy to imagine Wareham as a natural and far-reaching route centre. Here, in a region possessing the inestimable advantages of open or lightly wooded and low-lying country, the sea trader could meet the landsman coming down by short ridge roads leading from the encircling Downlands, nowhere far distant (see sketch map, Fig. 28, and full Ordnance Survey sheet). Therefore, not only was the port near a region of attraction, and doubtless considerable settlement, but, since the Western Downs lead north-east to Salisbury Plain, it may also have been in close contact with one of the very densest centres of settlement of prehistoric Britain. The above geographical reasoning does not postulate the existence of a prehistoric urban settlement in the present accepted sense, and it is impossible to suggest from the map alone the time when a town first grew up in the district.[2]

In relation to medieval requirements, it is obvious that the site which has special value as a meeting-place for both sea and land traders is a goal to be sought by invaders and a centre equally fiercely defended by the occupants of the land. The strength of the site as a base from which, for

[1] O. G. S. Crawford, *op. cit.*

[2] Though the importance of the site as a prehistoric port is hypothetical, actually the town site is known to be of high antiquity. According to many writers, the town walls date at least from early British times.

example, the Danes could overrun the interior needs little emphasis—hence the great need for fortification. The student of history may recall (and now appreciate the reason for) the frequency of Danish raids upon Wareham and the innumerable times the city was sacked and burned during the stormy times of early English history.[1] It seems probable that the line of approach—particularly during the Danish invasions—lay *via* Poole Harbour. But the route *via* Worbarrow Bay may equally have been utilized—perhaps to expose Wareham to danger of attack from both east and south-west at the same time. The following evidence may suggest the use of both routes.

(1) *The South-west Route.* 1½ miles north of Worbarrow Bay Lulworth Castle is marked, while the heath, located about two miles approximately south-west of Wareham, named Battle Plain on the Ordnance Survey map, may locate a site where many memorable encounters for the key site of Wareham have been staged.

(2) *The Sea Route via Poole Harbour.* At the south-eastern side of Brownsea Island again a castle guards the entrance to the bay. It is of interest to consider the especial advantages of this position. The island at low tide is surrounded by tidal flats—probably all but impassable for either an army from the land or a fleet from the sea. At high tide it is, however, completely surrounded by water, and then provides a fortified naval base wherefrom to hold the approach to the harbour, for no invader could enter through the single gap in the bay barrier (only a mile to the east) without detection from the castle.[2] Moreover, to defenders familiar

[1] The historical associations of the whole district are of no little interest. The reader may remember that Canute established his first headquarters at Wareham. It is worthy of note also that the first engagement of an English fleet occurred in A.D. 877, when Alfred's fleet at Swanage encountered Danish ships as they left Poole Bay.

[2] Old Admiralty charts of Poole Harbour (*e.g.*, No. 2175) show that the north-east corner of Brownsea Island has been considerably changed in shape by reclamation since 1878. In previous surveys the castle is shown to lie on a very narrow promontory almost cut off from Brownsea Island to form a separate islet; hence the position of the castle in former times was yet more impregnable, and the reason for its location on the southern side of the island was simply that at this point only did land then exist.

with both tides and the position of permanent channels, it must have been relatively easy to wreck invading fleets. One imagines that the strategy of the defence lay in holding the narrowed main channel, between the island and the northern spit.[1] If the unwary invader entered the bay at high tide, he might be blockaded to turn south and westward in an effort to round the island, with the risk that, as the tide ebbed, he would be stranded on the mud-flats long before regaining the main channel to Wareham.[2] If he entered at low tide, then the safer line of approach *via* the main channel would be more apparent; and so, finally, the approach to Wareham itself might be effected.

The precise location of Wareham seems to be related to three features: (1) the spur which divides the Frome and Piddle valleys, (2) the relative positions of the two rivers on their respective flood-plains, (3) the distance from the actual shore-line, beyond which lie tidal flats.

(1) From the "Fully Coloured" edition of the Ordnance Survey map, where relief is shown by means of both hachuring and contouring, the extent to which the spur continues below the 50 feet contour eastward can be gauged very clearly (and incidentally provides an illustration of the value of the addition of the hachure symbol in facilitating detailed map-interpretation). The sketch map in Fig. 29 is based on the hachured edition, and shows how—excepting the northern section of the town, which has grown over the Piddle flood-plain—the bulk of the city lies almost entirely on the terminal slopes of the spur, which, as the shading suggests, tapers to a point a little east of the eastern town wall. From the "Popular" edition alone this important detail of a minor topographical feature can in no way be

[1] This argument assumes that the spits have occupied approximately the same position at least since early historic times—perhaps a dangerous line of argument in view of the rapid changes in form which this land-form is known to assume. The presence of roads and of so many dwellings and the considerable height of the dune cover (according to spot heights on the original map) suggest, however, that the north spit at least may be relatively stable, and has maintained approximately the same position through a considerable time period.

[2] It is of interest to record from Admiralty charts that large sections of these flats are uncovered two hours after the turn of the tide.

detected. The value of so slight an elevation in a region which one may assume to be ill-drained and liable to flood can be deduced from a study of the roads in the vicinity.

The western ridge road is a relatively dry road, leading

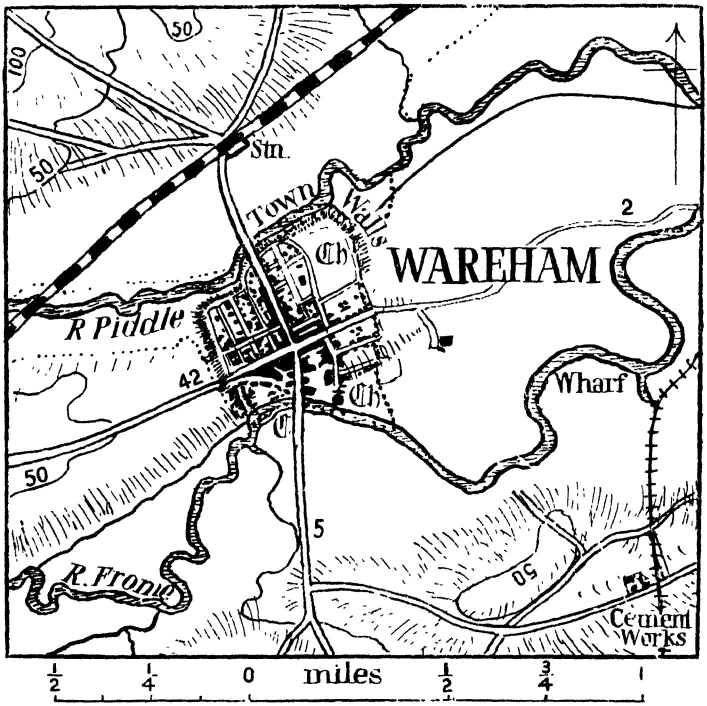


FIG. 29. THE SITE OF WAREHAM

C = Castle. . . . Parish boundary.

Based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office

directly into the heart of the city, where the latter lies predominantly on the ridge itself. But the roads into the town leading from both north and south must cross either the Frome or the Piddle flood-plain, together with the actual river, before the town can be entered. Even on the "Popular" map one is impressed by the way in which three roads

te on the extreme northern side of the Piddle valley and the southern side of the Frome valley, one road only in h case leading directly due north or south into the town lf. It might be suggested that the position of the road ction on each valley-side marks the margin of the flood- n, which, if liable to extensive inundation, would be ssed by the minimum number of roads.[1] This assump- ı gains value when it is noted how the railway—presum- y of more recent construction—follows a similar course l to the side of the valley, to pass through the triple road ction, where is situated the station for Wareham. These uctions are verified from the "Fully Coloured" edition, ere, as in the small sketch map, evidence as to the posi- ı of the valley walls and limits of the flood-plain at the d junction is rendered convincing by the hachure shading.

2) To the advantages of slight elevation one may add additional value which the relative position of the rivers y afford. Above Wareham the Frome and Piddle lie some ance apart, owing to the broadening of the intervening ge. Below Wareham it so happens that again they swing ely apart as they meander over a very flat, open flood- in, which they share. Wareham itself has grown just ere the two rivers approach each other more closely than ıny section immediately above or below. Thus the town grown in a quadrilateral of land bounded on two sides a water-front.[2]

he restriction of the land area between the two rivers . result partly of the narrowing of the spur, which brings two valleys naturally more closely together, but largely he pronounced curve of the Frome to undercut the banks the spur on its southern side. How far the advantages a double water-frontage predominated over the advan- es (previously suggested) of slight elevation it is difficult estimate; but the value for defence of two such natural l extensive moats (approached through plains which one

The single roads which cross the Frome and Piddle flood-plains are in ı case marked as causeways on the 6-inch sheet for this district.

Incidentally it is of interest to note that the name Wareham is said to lerived from the Saxon Wearth-ham—*i.e.*, 'the dwelling on the land veen two waters.'

may assume to be both marshy and forested) scarcely needs emphasis, and it is noticeable how the town seems to have been planned definitely in relation to these two rivers. That it was possible here to bridge both may have contributed to the importance of the site in no small measure; indeed, this may mark the first upstream position where bridging could be effected, or, it may be, the position of fords of even greater antiquity.

The Piddle, unlike the Frome, lies almost in the middle of the flood-plain, and therefore the expansion of the town to the river has meant growth over part of the flat plain. This seems to have led to the construction of walls on the north side of the town immediately behind the line of the river. To the south there seems no indication of the completion of the circuit of wall, and the hachuring on the "Fully Coloured" edition may provide an explanation of this fact. The shading shows that the intervening ridge is distinctly of asymmetrical form, and slopes far more steeply to the Frome than to the Piddle flood-plain. Walls therefore are not necessary on the southern side; indeed, the naturally steeper wall will have been over-steepened where the river, undercutting the spur, surely will have formed a meander scar. In this connexion it is of especial interest to notice that here again the castle (of which only the site remains) may have been built above the same natural feature already identified in relation to other examples (see Chapters VII and VIII).

It seems clear that when the town walls were first erected the water-frontage provided by the Piddle was yet more extensive, for the walls at the north-east corner of the town turn from the Piddle and curve abruptly to the south-east before the north-to-south direction of the eastern wall is assumed. This curve of the walls at the corner of the town is followed and continued north-eastward back to the river by the parish boundary, thus completing the course of a typical meander bend. If, as it seems not unreasonable to suggest, the Piddle formerly followed this curve at the time of the construction of the town, then the trend of the wall and parish boundary is explained.

It is not only in relation to defence that the water-frontage possesses many advantages, but equally in providing an invaluable economic asset. Particularly when the proximity to the head of Poole Bay is remembered, the rise of Wareham as a port at a position which could be reached easily by sea-craft in medieval if not in modern times seems highly probable. Thus the town may have functioned as a focus of economic no less than military importance. Evidence of this is perhaps less direct, but may be deduced by reference to the third factor tabulated as of local significance.

(3) This is proximity to the shore. Wareham lies but little over a mile from the head of Poole Bay, and it seems almost certain that at least in former eras boats of shallow draught, bringing either traders or raiders, could ascend directly to Wareham itself (the port for an extensive, if immediately unproductive, hinterland). The very position of the town unquestionably suggests strong maritime trading associations, but there are no harbours, docks, or extensive and crowded suburbs to indicate a thriving commercial centre. Direct evidence is suggested in only two cases, by the location of a wharf (north of the cement works, Fig. 29) and the naming of a hamlet (at Wareham railway-station), Northport. When the form and size of this old town are associated with the present absence of evidence relating to maritime activity, the possibility of decayed value rises to mind; indeed, considering the small size and likely volume of the two rivers, and the great depth of water required by present craft, this seems inevitable.

But there seems ample evidence of physical changes sufficient by themselves to cause the decline of sea traffic. Just as in the case of the Kingsbridge estuary (only here over a much broader area), both sea and rivers combine to build, if slowly, a plain which will eventually fill the whole bay. The present extent of the flats thus created can be most clearly distinguished on the old "Fully Coloured" map, where the former unsubmerged land surface—though of low relief—is identified by hachuring, while the flats of more recent creation occur where complete absence of any shading indicates very flat surfaces. Thus the broad flat below

Wareham may be viewed as a deltaic growth produced by the joint Frome and Piddle rivers. Doubtless in early historic times it consisted either of tidal flats, as around the rest of the bay, or of unreclaimed fen, partly inundated at high tide.[1]

When the changes due to deposition, together with the consequent decay of ports, are recalled in relation to other inlets around the British coasts (*e.g.*, Chester), it seems reasonable to conclude that the same process has wrought similar changes in this region. In view of the landlocked form of the bay, the process may actually have been much hastened. For at high tide not only will rivers empty their load into a veritable lake of calm sea water, but the latter, charged with sediment, will be ponded back behind the bars, and therefore may rapidly build up mud flats. The character of the silt-laden water which fills the bay may be gauged from the fact that the island to the east of the bay is named Brownsea Island. Much of the land bordering the bay is still very marshy, but drainage channels indicate stages in land reclamation—*e.g.*, in the neighbourhood of Wareham.

Wareham therefore may have shared the fate common to many other centres developed at the head of sheltered or landlocked bays. There seems no question as to the real medieval importance of the centre, in view of the size and form of the town at that time, but one imagines that decay set in at quite an early date.[2] Commercial stagnation has

[1] This would explain the existence of extensive marsh in the lower valleys of many rivers entering the bay (particularly at L, north-west of Wareham), marking areas formerly submerged. Spot heights within the lower Frome valley show that 1 mile from the sea the altitude is only 2 feet above mean sea-level, while even as far inland as the valley south-west of Wareham an altitude of only 5 feet is recorded on the flood-plain.

[2] Wareham was an important Domesday port, but Poole is not mentioned in connexion with fishing until 1244. The following extract from vol. i of *The History and Antiquities of Dorset*, by Hutchins, was written in 1774: "The tides formerly rose higher, and the meadows on the north and south side of the town were anciently morass and covered by the water at almost every tide, as they are even now on a spring tide, a south-east wind and a flood. They have been improved and made firm ground by cutting drains and raising the banks of the river within the memory of man. . . Certain it is that no maritime affair relating to this place occurs

allowed the preservation of the older city form, so clearly portrayed on the topographical map. This history explains the fact that the whole town still lies included within the same medieval walls. Not only have no suburbs grown without, to mask the remarkable regularity of the old town-plan, but, more significant still, there is no indication of pressure of population *within*, since one-third of the site—that in the neighbourhood of the ancient church marked in the north-east quadrant of the town[1]—is still open or only partly occupied.

Presumably to-day Wareham functions only as a market centre, for the convergence of land routes on the town will maintain to a restricted degree the momentum which former greatness established; but no longer can one visualize the passing of any considerable or important sea-borne traffic along the Wareham Channel. Proximity to the Purbeck limestones and to the clays of the Tertiary beds probably accounts for the only two local industries of any concern to the present inhabitants—*i.e.*, cement making (south-east of the city) and potteries (to the north, near Northport).

But the decay of maritime centres depending on harbours of this kind frequently implies only the shifting of activity to a position as yet unaffected by processes of harbour destruction. Poole seems to suggest such a centre, perhaps having grown in importance as the prestige of Wareham waned. The advantages favouring the growth of a seaport

after 1347, when Wareham furnished 3 ships and 59 men, sent to assist King Edward III. . . . Even at present, on great spring tides, the tide flows up to Holm bridge, near 5 miles by water. The shallowness of the river must be attributed to the quantity of dirt and rubbish carried into it by violent rains. In the Danish wars the town was sometimes partly, sometimes entirely reduced to a heap of ruins, which contributed greatly to choak up the channel of the river. And our ancestors were so sensible of this that a constitution of Stephen Rawlin, Mayor 29 H. VI (which was found so prudent that it was renewed in after times), prohibits sweeping the rubbish of the streets into the current on hard rains. . . . Now, a loaded vessel of 10 tons can scarce come up to the key, whereas some years ago one of 20 tons could be brought up."

[1] The church is marked in the open space in Old English type on the "Fully Coloured" edition, but is omitted on the "Popular" sheet. The 6-inch sheet shows that this area is given up almost entirely to allotment cultivation.

at Poole are clearly shown on the map. The town is almost entirely restricted to a small peninsula, which is connected to the mainland by a narrow neck of land on the one hand, while an exceptionally narrow channel crossed by a bridge carrying a main road divides it from the western side of Holes Bay, beyond which urban expansion has already begun. Thus the presence to both north and south of very broad bays capable of accommodating considerable numbers of craft (at least periodically, at times of high water) gives the site an almost insular character, while the bend of the tributary draining Holes Bay provides a permanent water-frontage for most of the peninsula at all states of the tide, and, moreover, connects directly with the main channel of the larger bay.

In relation to the size of the bay the port may seem relatively small in size, reflecting very probably the small area which is actually effective at all states of the tides. Further, it is to be remembered that even at high tide the larger area then flooded will be of value only for the harbourage of boats of quite shallow draught (*e.g.*, fishing fleets), since over tidal flats the depth of water depends on the height of the tide.

Assuming that at least within recent historic time the spits and harbour entry have maintained a relatively stable position and form, then Poole may have suffered from the very obviousness of the approach to the harbour. Since one quite narrow outlet alone leads to and from the harbour, it would be a very simple matter for a hostile navy or pirate to block the exit or lie in wait for the approaching fleet or single vessel, whether seeking to enter or leave the bay. Thus the trade of the port could be impaired by the menace of restricted facilities or direct blockade. In view of the form of the harbour, port, and adjacent hinterland it seems clear that Poole has grown not as a great industrial centre, but as one of the larger fishing ports of the English Channel, probably also engaged in exporting the local products of the town and district derived from the clays and the actual pottery manufactured near by.

Remote though the fate at present seems, yet at some

:ant date one may visualize in the case of Poole a repeti-
ı of the history of Wareham, though in the case of the
ner this decay will be related to very different historic
l economic associations. It is questionable whether the
ue of the port will ever be such as to justify its perpetua-
ı by the dredging of the silted bay. But before this phase
been reached, great changes will have been wrought
the physical form of the bay above Poole Harbour as
esult of natural processes of sedimentation, doubtless
tened by land reclamation. Whatever the fate of Poole
y be, these circumstances will surely lead to yet a further
line in the importance of Wareham, for no longer will
ds and railway be forced by a wide *détour* from Poole or
anage to pass along the margin of the bay through this
centre. To-day routes diverge as northern and southern
ıs bent around a large oval unit which is transitional in
physical history as in its human values—a core of land
he making, which from the point of view of transport is
ther land nor sea, and cannot be crossed by the means
ropriate to either. For this reason it is at present an
nhabitable area isolating north from south, but for the
ıe reason it may be in the future a favoured zone into
ch settlement will gravitate, and which therefore will
: together north and south.

ın island-studded, fen-bordered tidal bay, a transitional
: of open heathland, and a peripheral upland of chalk
wns—these three units have formed the geographical
ing for the successive phases of human occupation. Re-
kable in its scope—often remarkable for its clarity—the
p presents scattered, perhaps incoherent, but neverthe-
convincing evidence of the rhythm and change which
racterize our seemingly stable environment. The changes
ettlement—from *pre*historic concentration on the Down-
l to the possible *post*-historic attraction of the reclaimed
—afford but one illustration of the fact (sometimes over-
ced) that the present age is in reality as transitional as
e been preceding eras, and is not necessarily a fixed or
l adaptation of man to his environment.

The student should construct a sketch map to show a

possible distribution of settlement and the lines of communication (with special reference to changes in the value of existing centres) when the whole bay is replaced by plains. It will be advisable to study the remaining pages of this chapter before attempting the exercise.)

Shallow Seas and Land Growth

The area shown in Map XXIII differs from any of the coastal regions studied previously. This region, comprising part of the West Somerset coast, includes several small uplands—in most cases of very abrupt relief—which lie separated from each other by low plains, equally conspicuous in their featureless relief. Both physical types run out to the shore-line itself, the uplands forming headlands, the plains a sequence of slightly receding bays. The uplands trend in general from east to west, and are located each approximately in alignment with inland ridges—a characteristic especially noticeable on the full Ordnance Survey sheet. On this section the feature is particularly illustrated in the case of Brean Down, which continues in shape and direction the line of the adjacent Bleadon Hill, itself the western end of the steadily tapering wedge of upland which the full sheet denotes as the Mendip Hills. The ridge so strikingly isolated above Weston-super-Mare (*i.e.*, Worlebury Hill) seems to continue the direction of the uplands east of the river Yeo, while the full sheet clearly shows how Middle Hope Hill to the north follows the direction of the Clevedon Hills, 4 miles beyond to the north-east (see Fig. 30).

From the evidence of drainage, as from relief, uplands and plains seem to comprise rocks of very different geological formation, for the former are regions everywhere deficient in surface drainage, while the latter are characterized by a copious or superabundant water-supply, indicated by the very extensive system of drainage channels. The evidence of the map suggests outcrops of limestone in the Mendips; in all probability the plains, on the other hand, consist of saturated alluvium with a very high water-table.

The origin of these flats is clearly not related simply to

river action, for rivers, where present, are not large enough alone to have created them. This is clear not only from the size of the Yeo river, but also from a glance at the more diminutive Lox Yeo tributary of the Axe, whose very wide valley penetrates the Mendip ridge. Reference to the work of the sea within this locality provides an explanation as to the formation of both flats and the isolated hill promontories.

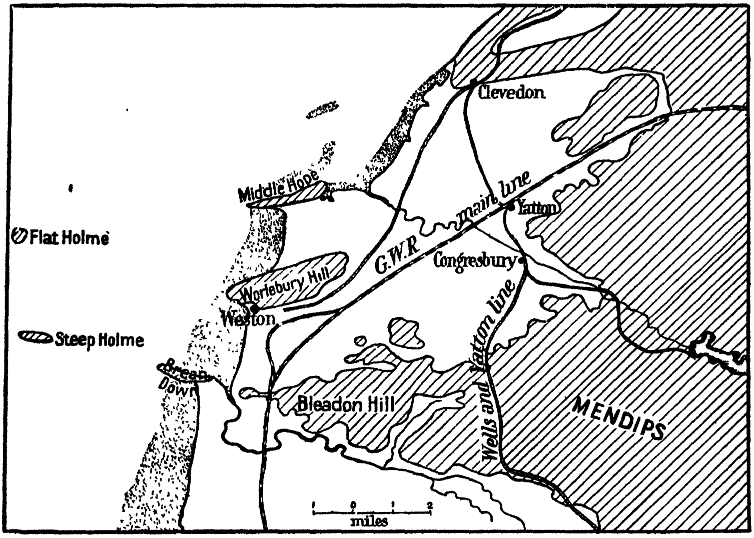


FIG. 30. SKETCH MAP OF WESTON AND ADJACENT DISTRICT

Land over 50 feet shaded.

A noteworthy feature is the gentle offshore gradient into the Bristol Channel. At a distance of 7 miles or more from the shore-line (according to the full sheet) the depth of water may be but 5 fathoms, while locally shoals and sand-banks are exposed at low tide—*e.g.*, at A. These features suggest that constructive rather than destructive marine action is predominant, except locally, where the ridges run out to the coast, to end in sea-eroded cliffs.

The full sheet shows that two small offshore islands of a rocky nature occur in alignment with the coastal ridge promontories (see Fig. 30). If these have been isolated from

the mainland by sea erosion, this implies the removal of a zone of land at least 3 miles wide in a region where it seems unlikely that strong wave attack could occur, for the shallow water must dissipate wave energy.

The more recent physical history of the region becomes clearer when considered in relation to the submergence which caused the formation of the Bristol Channel. The small islands, isolated from the coast, are of interest because they may epitomize a former phase in the physical history of the Weston district. As these are at present still surrounded by sea, so the three abrupt promontories at the coast (flanked partly by land and partly by sea) were at some former time completely surrounded by sea within what was then a far broader and more indented Bristol Channel. The flats behind Weston-super-Mare may therefore be viewed as plains formed by extensive deposition in formerly rock-bound and island-studded bays. The existence of these islands has been determined by considerable submergence, sufficient to break the continuity of formerly continuous ridges by the drowning of lower passes. Bleadon Hill may represent an even earlier phase than is exemplified by the present coast ridges, for though it can with less certainty be suggested that this hill was ever completely isolated (since it is not surrounded entirely by plain, a col rising to 127 feet at X), yet undoubtedly at some time it formed an irregularly shaped peninsula, washed by the sea on almost every side. Combined processes of marine sedimentation and the accumulation of land detritus have led to the seaward growth of the flats to their present position; and, as the extensively sand-bordered shore-line would seem to suggest, the processes of land formation by marine action are still active. Levelled though the present plains may be, we should visualize the old, sub-aerially denuded surface (now underlying the sediments) as probably of irregular configuration. (For example, an irregular surface may lie buried beneath the plain between Worlebury Hill and its continuation east of Congresbury village.)

In certain respects this region epitomizes the physical form of the East Anglian fen-lands. The present section of the

1-inch map was chosen to exemplify this type of environment because, unlike sections from maps of the more 'classic' examples of fen-land in the eastern counties (where unsubmerged ridge-summits are of lower altitude and more subdued topography), this shows many typical features within one small section, with far more decided contrasts to aid recognition—at least from the point of view of map-interpretation. There is, however, no indication of the stages passed through in the process of land-building, for it has been possible by human intervention to change entirely the form of these flats by land reclamation and complete drainage, practically to the shore-line. This is proved by the presence of innumerable drainage channels, identified by their patterned system and broken course. These drain the plain as a whole, while the main rivers are heavily embanked for a considerable distance inland (see both the Axe and the Yeo). The embankments may in part be natural, due to the building of levees by the sluggish, meandering rivers, but it is probable that in considerable part they are artificial, especially in the case of the Yeo, where they extend continuously as far as the shore-line, which they follow both immediately and also at a distance of about half a mile inland. These seem to be coastal defences directed against sea encroachment, for on older Ordnance Survey maps two of the farms were marked with the distinctive name of "sea-wall farm." Apparently there is need to protect the plain now reclaimed for agriculture from the occasional (but none the less devastating) floods which unusually high tides and storm winds may cause.

The damage which might then be wrought can be estimated when it is noted not only how the land immediately behind the shore-line is devoted in many cases to agriculture, but also how low is the relief of the interior. Nowhere does the reclaimed land rise to an altitude of 50 feet; rather is the larger part less than 20 feet above mean sea-level. A careful study of the spot heights shows the need for river embankment far inland, and exemplifies a feature particularly characteristic of this type of reclaimed land. Practically everywhere a reversed slope may be traced, which,

though very slight as regards actual degree, is sufficient to prohibit a complete natural seaward drainage of flood waters. At a distance of $2\frac{1}{2}$ miles inland from Sand Bay, for example, the spot height records an altitude of 21 feet, while due east, in the neighbourhood of Congresbury, the land falls to 15 feet. Similarly, just south of Worle village, altitudes of 23 and 17 feet occur, while some 5 miles eastward the level has fallen to 16 and 15 feet. (Compare the evidence also from spot heights shown on Map XXV.)

The greater altitude which typifies the immediate shore-line in many districts suggests that a beach barrier may have been constructed naturally to form a dune ridge. This would explain, for example, the absence of sea-walls in Sand Bay (where a spot height of 30 feet is recorded), for the natural sand barrier may be so strong and high that artificial defences are not necessary along this section of the coast. On the full Ordnance Survey sheet there is a broad dune belt marked definitely as rising to the same altitude along the bay shore south of Brean Down, while the accumulation of considerable deposits of blown sand seems inevitable when one recalls the exceptional width at low tide of the drying sands, across which westerly winds will blow, picking up a heavy load. But the lower altitude of the interior may also be due to processes of natural subsidence, for the inland flats were the first to be built, and probably the first to be reclaimed from the condition of fen. It is a characteristic of such land reclamation that subsidence does occur with the removal of the water from the fen soil. The longer this process continues, the greater will become the need to embank the Yeo, for if the course of the river remains unrestricted, then widespread inundation can occur, and free drainage to the coast from the flooded interior would be checked by the slight rise in elevation to the west. A shrinkage to cause a subsidence of about 5 feet by this process would not be excessive.

Human Considerations. The change in the land values during historic times seems more apparent here than in almost any of the regions previously considered. The exceptional prehistoric and early historic value of the limestone uplands

amid a 'sea' of fen and unreclaimed marsh is exemplified by the profusion of camp sites, both British and Roman, and of earthworks and tumuli, etc., on these uplands. The reader should try to visualize this region in former times—when standing, for example, on the Mendips and looking northward over perhaps a desolate, lake-studded sedge-land, broken by what would seem to be remarkably abrupt hills clothed with open grasslands. The importance of ridge routes through this extensive morass is indicated by the site of the Roman road which trends along the Mendip summits and Bleadon Hill. Brean Down and Worlebury Hill illustrate the exceptional value of these upland 'islands' as sites for prehistoric or early historic hill villages. Both are crowned by camps. Worlebury Hill would be large enough to support no inconsiderable population on the dry limestone slopes and pastures, with the camp as a safe retreat on the hill summit. The whole settlement would be isolated on almost every hand—westward by the sea and eastward by the fen-land and morass (equally impassable)—while, in addition, the steep ascent from the plain would have made the site almost impregnable. In such circumstances one might ask how contact with the outer world could have been maintained. Apart from possibilities of communication by sea, there seems to be only one landway by which the hill site could be approached or abandoned at any season (except, perhaps, during exceptional storms). Already it has been shown that just behind the shore-line the land is slightly higher than farther to the east, and that probably—at least within Sand Bay—the shore-line is bordered by sand-dunes or beach ridges, beside which a dry and open way, flanked by sea and fen, might provide a natural causeway southward to the Mendips. This way would be of inestimable value in the winter season, when heavy seas might prohibit primitive navigation. The fact that a sea-wall is not necessary as a coastal defence to-day, and that Weston has grown along almost the immediate shore-line (which therefore lies well above the influence of storm waves), suggests that the above hypothesis may be tenable unless marked coastal changes have occurred within relatively recent times.

The map-reader may turn with far greater certainty to consider the human geography of the region of to-day. As one would expect, plain rather than upland provides the zone of attraction, to reverse completely the early distribution of settlement. The innumerable orchards in the region show how very largely the area is devoted to fruit production, for which the rich alluvial soils, undoubtedly of very mixed origin, are especially favourable. In detail, it may be noted how the orchards, which at first glance seem to be irregularly distributed, in fact are concentrated closely on the better-drained lands. Particularly are they located on the lower flanks of the limestone uplands in the neighbourhood of the 50 feet contour. But they also occur on the plain in groups that are densest where there are fewest drainage channels, and therefore presumably where the soils are relatively dry—or, it may be, where very low knolls stand unburied by fen sediments. (This is the case, for example, at B, where a low round knoll exceeds 50 feet in altitude.)

To the same cause may the distribution of villages be related, for they do not occur irregularly, but seem to show an especial relation to slope. Just as in the case of the Wealden district (Map III) or the North Pickering unit (Map VIII), here again they exemplify the fundamental principle that "human establishments preferably select lines of contact between different geological formations."[1] The largest villages are crowded along the upland flanks, in a position which therefore avoids both the flats of superabundant water-supply and the over-dry limestone uplands. At the same time, not only are the villages centred over the most favoured orchard lands, but they also form a link between the two contrasting economic units provided by upland ridges favouring sheep pasturage and the rich, damp pastures devoted to cattle-rearing. That the latter is an industry of some local importance may be suggested by the presence of tanneries (*e.g.*, at Claverham village) and by some of the farm names on the Ordnance Survey sheet (*e.g.*, Bullock's Farm). (Note particularly the hillside placement

[1] P. Vidal de la Blache, *Principles of Human Geography* (1926).

of villages in the Lox Yeo valley, breaching the Mendips.) The exposure of the region to westerly winds is implied by the presence of innumerable windmills on the plain and wind-pumps on the limestone uplands.

In addition to these villages of the fen margins, there are other small orchard hamlets scattered over the reclaimed plain, together with a number of isolated farms. Across the fen plains the difficulties of finding firm ground will restrict free road construction and village growth. Since roads often demarcate natural *terra firma*, or follow artificial dikes bordering the drainage channels, it results that villages grow as a single line of dwellings bordering the roadside—for probably nowhere else can a relatively firm foundation be found. Just as in the Vorder Rhine valley (Map XVI), where the villages on the sun-facing valley-side suggest the form of the *Waldhufendörfer* (the straggling roadside settlements in the mountain forest clearings), so the same village type characterizes the reclaimed fen plain, although the *Marschhufendörfer*,[1] or 'marsh villages,' are related to so different an environment. It is particularly interesting to notice the form of Congresbury, Horsecastle, and Yatton villages, and to compare these marsh villages with the mountain forest villages of Map XVI.

Physically the Somerset district offers an extreme contrast with that of South Devon shown in Map XX. Nevertheless, the interests of the population here, as there, are primarily bound up with the land and not with the sea. Weston-super-Mare, the one urban centre, is an exception to this generalization, for it is obviously a coastal resort. But it has grown in relation to the requirements of external foci, and has developed as a centre out of harmony with the remaining district. Though it probably includes a high proportion of the total population of this region, at the same time in no sense does it represent the interests of the mass of the area. It seems unlikely that the town will have grown

[1] These comprise the two divisions of the *Reihendörfer*, or street villages, according to Meitzen and others. For summary classifications, etc., see the paper by Professor Demangeon, "La Géographie de l'habitat rural," in the *Annales de géographie*, vol. xxxvi, 1927, pp. 1–23, 90–114.

from an older fishing centre, since the bay is sand-filled and the water so shallow. To-day a pier extends almost half a mile seaward, while at low tide the sea retreats more than that distance beyond the pier-head!

The course of the railway similarly indicates how restricted is the importance of this centre. The main line sweeps south-westward across the plain to curve round the Mendip ranges toward the external centre of Bridgwater. It passes almost within a mile of Weston, and yet avoids the slight *détour* which would include the town, though there appears to be no technical difficulty to prevent this. Weston is served by a branch loop, but the fact that this is a double-track branch line suggests a considerable tourist traffic for Weston itself.

The remaining region is served by other local lines which, typical of local agricultural traffic, are single-line railways, with frequent stops at small hamlets or 'halts.' These lines, it should be noted, trend almost at right angles to the route followed by the main line, which is planned in relation to external centres rather than local needs. Local lines therefore run both from the tourist centre in the west and from across the Mendips in the east northward to the external local centre of Clevedon (see sketch map, Fig. 30). It is of interest in connexion with some earlier conclusions to notice that Weston, the one urban centre, is by no means the most important railway focus of the area shown within this map. It seems more reasonable to suggest that Yatton, though but a village, is a local focus of far more general importance within this small region, for here the branch railways from north or south and from the south-east meet the main line to Bristol, which regional capital lies but 10 miles beyond this district.

It may be that features which will characterize Poole Bay in its later history are represented in the physical and human geography of these plains. It is, however, impossible from Map XXIII to visualize the exact manner and rate of land growth and reclamation, though in maps of other regions there may often be sufficient evidence to render this possible. This is the case, for example, on Maps XXIV and XXV.

Map XXIV typifies a coastal plain in the early stages of

formation by marine deposition. Against an abrupt though low rise (indicated by shading), which may possibly identify the position of a former shore-line, a plain has steadily been built seaward, until at the present time a belt of reclaimed land about 1 mile in width lies protected from inundation behind a sea-wall. Beyond this the work of the sea, unaffected by artificial interference, is depicted.

Passing inland from the offshore sands, which are exposed only at low tide, a sequence of land-forms is encountered typical of marine action. The shore-line itself is bounded by a shingle and dune ridge, protecting large tracts of lagoon and salt marsh which at high tide are almost entirely inundated. Here tidal silting in the sheltered waters is building up a flat plain surface, probably with the aid of marsh vegetation. Between Burnham Harbour and Scolt Head there lies a complete offshore island composed of the dune shore ridge which slopes down to the tidal marshlands. At low tide this pseudo-bar is connected by mud flats with the land marshes and reclaimed plain. With regard to its origin, there are two alternatives which one might suggest from the map:

(1) Scolt Island may be an offshore bar which has either been formed in its present position or has rolled onshore from a position farther out to sea, in the manner characteristic of such land-forms. (Fig. 31, for example, illustrates a bar which, unlike the example suggested in Map XXIV, lies some miles out to sea. The map shows clearly how it is formed off a submerged coast-land of very subdued relief, and where the continental shelf is sufficiently gentle in slope to cause waves to break some distance offshore, at which position the bar will have been built.)

(2) In the case of Scolt Island, however, there is one line of evidence which suggests that the feature is not a bar of the above type, but merely part of a broken spit which has grown by longshore drift in a direction from east to west.[1] For the bar terminates in a broad wedge of recurved spit

[1] For a discussion as to the origin of these and adjacent shore-forms see J. A. Steers, "The East Anglian Coast," in the *Geographical Journal*, January 1927, and later publications.

ridges at its western end, where presumably accretion is most strongly proceeding. Scolt Head is, indeed, simply typical of a normal spit-head and differs considerably in

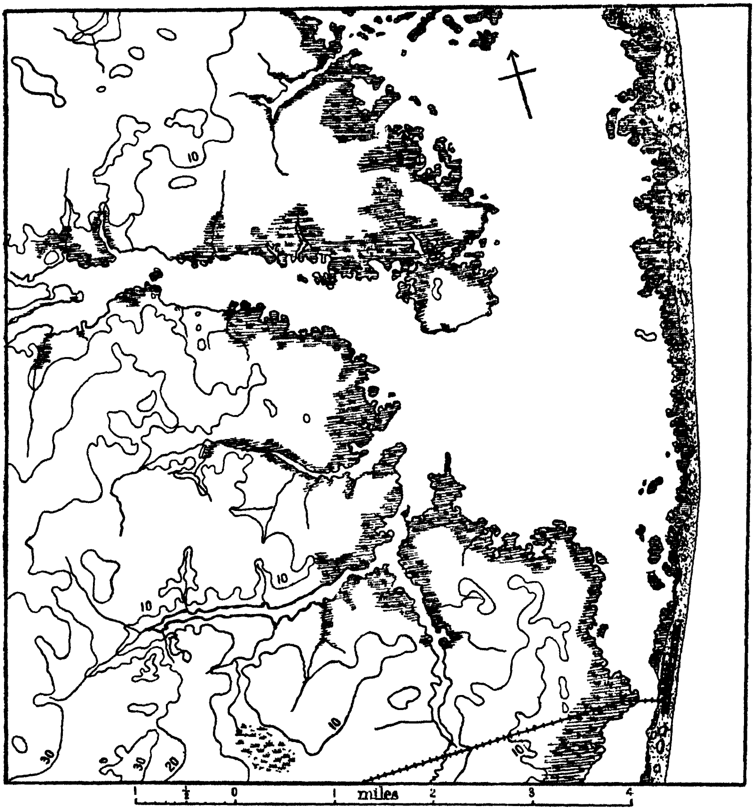


FIG. 31. OFFSHORE BARS

V.I., 10 feet.

Based upon the Ocean City quadrangle (Maryland) of the U.S.A. Geological Survey, with permission

detail from the eastern end of the island. It is difficult to see how Brancaster Harbour originated—threaded as it is at low tide by a river channel linked to Norton Brook—unless the latter, before entering the sea, was turned suc-

cessively farther and farther to the west by a steadily lengthening spit. If this is the case, then the breaching of the narrowed spit at Burnham Harbour simply illustrates a common phase in the history of these shore-forms.

Lastly, and most important, is the occurrence of what appear to be relics of recurved ridge ends at intermediate positions along the spit—*e.g.*, at XY and at Z. The ridge XY is clearly of earlier formation than is the present head at W, which is lower, duneless, and occupies a more advanced westerly position. Furthermore, the present spit front (between Y and Burnham Harbour) cuts across the XY ridge to form an angle more acute than that through the present spit-head W. This suggests that the whole spit is undergoing a double movement. In the first place there is a recession landward as a result of the paring and truncation of the spit-front, while at the same time material from this is swept westward to accumulate in the neighbourhood of the spit-head, and therefore to cause growth westward contemporaneously with recession southward. The position of the spit-front at the time XY formed the head may be visualized, therefore, as slightly seaward of the present line between Y and Burnham Harbour. Z, which forms a less conspicuous shingle ridge, but one which cuts deeply into the marsh tracts, may represent an earlier analogous case, and depict relics of an old spit-head which is now so truncated that only a small base still remains. Originally it may have been connected with a spit lying yet farther seaward, beyond the suggested position of the spit-front for the head XY.

In conclusion, we may trace from Map XXV the possibility of timing the work of both the sea and man in land-formation. Obviously the land has been reclaimed, for the region is traversed by drainage channels. Then, too, the coast, where unprotected by substantial dune ridges, is flanked by sea-walls. We may note again the evidence of spit growth and river diversion—in this case to the south, indicative of the normal southward drift which characterizes the east coast of England in general. Inland the reclaimed land seems again to show signs of subsidence, evident from the spot heights marked near to and north-west of the road from

Skegness to Wainfleet which on some Ordnance Survey sheets is marked as of Roman origin.

Evidence of quite rapid land growth within historic time seems to be indicated south of the Wainfleet river. The coastal region can be divided into three belts; two of these are named Old Marsh and New Marsh; the third we might ourselves name Newest Marsh. For whereas the first two have been reclaimed successively, and have been long devoted to agriculture (compare "New Farm" in the Old Marsh belt and "New Marsh Farm" in the second belt), the Newest Marsh belt is one of only recent formation—presumably in large part since the construction of the sea-wall bounding the New Marsh. The steady seaward advance first of marshland and later of reclamation seems indicated by the parallel trend yet farther inland of relics of another sea-wall, now fully a mile from the sea, and bordering the Old Marsh belt. It is clear that the sea has within historic time extended far inland beyond the present coast-line.

Land growth seems to have been less rapid or non-existent farther to the north. Interesting evidence of this is afforded by the sinuous line, varying in position from a few hundred yards to fully a mile from the shore, named as a bank of Roman origin. This suggests an approximate date since which this section of the coast may have grown seaward to its present position beyond this old coastal defence.[1] It may have functioned as a coast highway, for it seems to continue the line of the Roman road from Wainfleet to Skegness, and perhaps in part if not entirely utilized a line of wave- and wind-built ridges bordering a shore-line, then close at hand (just as the same land-forms border the present shore, now some distance to the east).

Wainfleet is of considerable interest, for here, according to older O.S. maps, was the Roman camp of Vainona. Judging from the location, it may have functioned as a seaport or have held a position where the Wainfleet could be bridged or forded in continuing the coastal road. There is evidence, however, of a further economic attraction which doubtless lent importance to the site. For here, fully 1 mile

[1] See full sheet for the northward continuation of the Roman bank.

to the south of the camp (note carefully the orientation of the map), there are indications of an attempt to develop in this coastal position a very characteristic Mediterranean industry. Whether the brines of salt marshes were used for salt-panning at the Roman salt works marked here, or whether the station was at that time sufficiently near to the sea for sea-water to be used directly, is a question which the map alone cannot answer, great though its interest may be.

It is fitting that we leave the study of these fragments of topographical maps with this last glimpse of Roman Britain, for it is from the British 1-inch Ordnance Survey map that we may gain—almost to an unrivalled degree—a true perception of the completeness of the Roman penetration—a penetration resulting in an occupation which, if at times superficial and spasmodic, did exert a direct influence during three hundred years. One cannot but be struck by the variety and profusion of traces of this occupation which the topographical map illustrates. Few are the sheets which mark no single relic. A reconstruction of topography, natural vegetation, and economic attractions from this evidence impresses upon the reader the fact that Roman legions or trading colonists marched to a few important route centres not only along the 'permanent way' provided by the greater Roman road arteries, but also *via* by-ways, penetrating deeply and widely to quite local centres in the heart of the province.

To conclude this study of topographical maps it is not inappropriate to interpret sheets of the Gold Coast survey, chosen because these depict the task of developing a new land in a strange environment, comparable in this respect, then, to the work of the Romans during the opening phases of British history.

CHAPTER XII

AN INTERPRETATION OF SHEETS ACCRA AND KOFORIDUA

(Gold Coast Survey $\frac{\text{North B–30}}{\text{L.IV}}$ and $\frac{\text{North B–30}}{\text{R.II}}$, 1 : 125,000 1st Edition, 1922)

Sheets Accra and Koforidua[1] depict a region of approximately 1500 square miles, an area so large that only a general geographical analysis can here be attempted. Preparatory to study, the two sheets should be cut and joined together along the common parallel (6° N.). The margins of the combined sheets may then be numbered and lettered, using the parallels and meridians as grid lines. Starting from the south-west corner, the divisions should be lettered in the margin from A to L for each 5′ of latitude, and numbered from 1 to 6 (with an extension at the southern margin of sheet Koforidua to 8) between successive 5′ of meridional divisions. This system will be used in the present text for references to localities.

Secondly, it is necessary to spend some little time studying the characteristic sheet of symbols appended to every sheet of the survey. This affords an excellent illustration of the scope of map symbolism, for the key includes no less than eighty-nine symbols, ranging from that which indicates the native fetish temple or the lonely rubber-hunter's camp to those denoting wireless stations or railway and telegraph lines! Noteworthy, too, is the range of information relating to the vegetation of the region. Rain-forest, scrub, and park-land, together with a great variety of tropical plantation crops, are each individually represented by appropriate symbols. Finally, before attempting the geographical analysis, the scale of distances must be appreciated—in this case approximately 2 miles to the inch.

[1] It is assumed that the reader has access to these sheets, which for the purpose of this chapter relate only to the edition published in 1922.

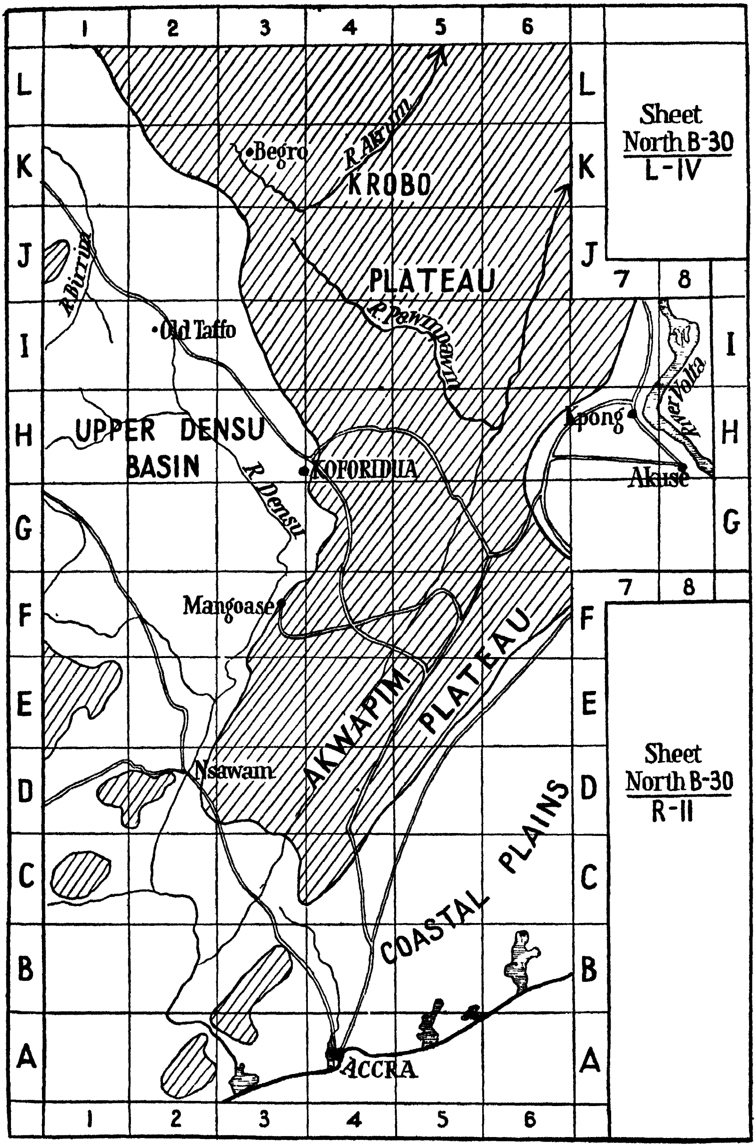


FIG. 32. SKETCH MAP OF ACCRA-KOFORIDUA DISTRICT (GOLD COAST SURVEY)

Scale approximately 13 miles to the inch.

General Survey of Relief and Drainage in Relation to Geological Structure

From a study of the direction and relation of river basins one to another, and an analysis of the details of relief no less than of the general characteristics of the major physical units, one may collect evidence to suggest that the physical history of the region has been related to (1) the planation of a complex sequence of outcrops of relatively hard rocks varying in their resistance to denudation, which strike—at least in the east—in a general south-west to north-east direction; (2) three (or it may be four) successive phases of uplift, each approximately to the extent of 500 feet, associated with a general northward tilting of the block. These two factors have together determined that the present drainage systems—antecedent in character—have been subjected to a considerable degree of diversion, causing somewhat anomalous relations between tributary and main streams or between adjacent river systems. There is space here to enumerate but briefly some facts supporting these statements, and the student should read the map for himself for additional evidence.

The Akwapim and Krobo uplands comprise in general a dissected plateau tapering south-westward to a narrow point in the vicinity of Accra. The orientation of the ridge, which extends from A2 to G4–6, identifies the direction of the graining of the region, and this direction is repeated over a very large area not only by river systems, but also by minor ridges and vales—*e.g.*, the ridge between Kunkunu (D4) and Addukrum (G6). To the north-west the form of the Krobo plateau suggests a change in this direction. The plateau here drops to the plains by a very conspicuous escarpment (L1 to H4), whose direction is repeated by a sequence of less pronounced edges—*e.g.*, Akwad to Akukaw, Kawam to A1–J3, and Aiyesu to Kokone, thence to Akankase (L3–K4). The plateau as a whole slopes from south-west to north-east, in keeping with a unit tilted in this direction during uplift.

Drainage systems have therefore developed particularly in relation to these two directions—*i.e.*, south-west to north-

east and transversely from north-west to south-east. It is necessary but to instance the directions of the Pawmpawm (J3–H5, thence to K7), the Akrum (K2–L4), or the Densu, which zigzags from north-west to south-east as far as F3, thence from north-east to south-west to C2, and finally doubly repeats these directions by abrupt bends between C2 and the coast.

The uplift of the plateau in intermittent movements (each roughly to the extent of 500 feet) is revealed from a detailed inspection of plateau altitudes. From coastal plains, in general bounded by the 250 or 350 feet contour, the land rises abruptly to terraces approximating to the altitudes of 500–750 feet, 1000–1300 feet, 1600–1750 feet, and, over a more limited area, to 2000 feet. A correlation of altitudes reveals traces of the lowest terrace in the plateau fragments trenched by the Densu water-gap (A–B, 2 and 3) and again at Ashefla (C1), while the plains between G and I (1, 2, and 3) record similar heights (see also the smaller, but none the less important traces at Peprao, Adadeiao, Ebrim, etc., D3–E3).

An abrupt rise to the 1000–1300 feet levels can be identified immediately west of Aburi (E4) and along the Aboasso-Apirrade ridge (C4–G6). The same summit levels may be cited from such widely separated areas as the Konko district (G4 and F4), from E1 and J1, and from the isolated hill immediately to the south-east of the Pawmpawm river in I5, and yet again in the case of the remarkably abrupt elevation, the Krobo Hill (G7).

The third level, varying from 1650 to 1800 feet, is especially clearly revealed along the escarpment border overlooking Osino and Koforidua (K1–H3). The student should collect further evidence from other districts (*e.g.*, L3, or Kawam (J3–K3), H6, I6, and perhaps I1). Finally, J2, Kokone (L4), Akwad (L1), and Akukaw (K2) reveal traces of the 2000 feet level.

It seems evident, therefore, that the association of alternating terrace and escarpment and of a remarkably patterned drainage, together with a strong development of wind-gaps and, more locally, of water-gaps, has resulted not only from

the geological graining of the land, but also from the repetition of the geographical cycle of erosion, interrupted by uplift and tilting. Particularly does the patterning of the river systems become evident when adjacent sheets are also studied. Thus the bends of the larger Volta repeat the directions of the far smaller Densu, and even of its own small tributaries, while the low gaps which so frequently breach the plateau (and largely determine the positions of the isolated monadnock-like ridge summits) in the same way lie either transversely to, or parallel with, the assumed strike direction of the rocks, seeming, therefore, to suggest that much diversion of former stream courses has occurred during earlier cycles. One may note, for example, the discontinuous water line from D1 to K6 *via* the Kran, Pampan, and middle Densu, and thence by escarpment gaps to the Pawmpawm headwaters. Especially conspicuous, too, is the breach (at 750 feet) followed by the road leading north-east from Koforidua. At right angles there trends the pronounced stream direction from L1 to H5.

A factor of first importance in causing river diversion will be provided by the contrasts in the gradient of north-flowing and south-flowing rivers. The drainage of the district, whether considered as a whole or in local detail, reveals the importance of the law of unequal slopes in this respect. Thus the major south-flowing Volta (of which but a small section is shown here) as a scarp river may have cut back and diverted ultimately to a southward course all the plateau rivers of gentle gradient and formerly of northward drainage. Though the sheet margins cut across the map to exclude the section depicting the actual river junction, the fate of the plateau Pawmpawm drainage seems obvious, and one can readily visualize the well-marked fish-hook bend which must exist at the elbow of capture, where the latter joins the Volta.

In miniature, the same struggle and ultimate victory of scarp *versus* plateau rivers is revealed time and again from a close inspection of the streams of the upland borders. The student should mark the water-parting carefully from L1 south-eastward between scarp and plateau drainage,

noting examples of capture achieved or imminent—*e.g.*, the Nsukwao (H4), above Koforidua, also the diverted Niensi headwaters, which now form the headstreams of the Nsaki (E4). The gently graded Pawmpawm system may almost be viewed as a prize for the possession of which not only the vigorous Volta, but also the more western coastal streams struggle keenly.

As a result of these changes there is a pronounced reversal of the normal sequence of valley gradients whether considered in relation to general systems or local tributaries. Thus it often happens that a river in its upper course flows in an open valley of very mature form, while in its lower course it becomes restricted to a narrow youthful gorge, where an aggressive stream, by virtue of a steeper gradient, is cutting back deeply to entrench the diverted and at one time gently graded plateau river. This process is particularly well exemplified by a comparison of the cross-sections of the Pawmpawm and Akrum rivers in their upper and lower courses.

The coastal plain south of the Akwapim plateau is a physical unit of relatively slight relief, traversed by water-courses of small volume, often rising as escarpment streams. At the coast itself the mouth of even the smallest stream has been blocked by what appear to be beach deposits, so that a series of small estuaries have been converted into coastal lagoons; generally where sedimentation has proceeded apace these are partially filled or bordered by marsh—in view of the latitude, probably mangrove swamp. The bars across these inlets may have been formed by the action of littoral currents transporting shore *débris*. Alternatively, a slight elevation of the land to form low, raised beaches might account for the repeated formation of the lagoons, as in the case of the Slapton lakes of South Devon (see Chapter X).[1] If this explanation is correct, it may be that the formation of the lagoons

[1] A similar explanation for the coastal lakes of this district does, indeed, hold true—see A. E. Kitson, "The Gold Coast: Some Considerations of its Structure, People, and Natural History," in the *Geographical Journal*, November, 1916.

merely depicts a continuance of the processes whereby the whole coastal plain has been formed; the present character of the plain itself and its relation to the plateaus inland are in keeping with such an origin—primarily, that is to say, as part of an elevated continental shelf.

The shore-line itself consists of alternating bar and low cliff (the latter seldom approaching a height of 50 feet), but seaward the gentle gradients of the plain are continued across the continental shelf, as may be measured by interpolating 5 fathom sea-contour lines. These trend parallel with the coast-line, and show how, for example, at Accra a depth of only 30 feet may be registered at a distance of 1½ miles out to sea, while not until 3 miles distant from the coast is a depth of 60 feet reached.

Vegetation and Climate

The latitude of the region (5° 30′–6° 30′ N.) gives reason to expect evidence of equatorial climate, and this is revealed from a study of the vegetation, fortunately shown in great detail, by a large number of symbols. Apart from the many tropical plantation crops which are shown (and whose distribution may be limited by very definite climatic requirements), the map portrays separately the distribution of forest, scrub, and park-land—plant associations whose growth is closely related to rainfall. From a study of vegetation, both natural and cultivated, it becomes evident that a zone of low rainfall, increasing in width to the east, extends from the coast over the plains, roughly as far as the plateau margin. This is a belt of open country or thin park-land. Tree symbols—where these are indicated—are quite widely separated, and no plantation crops requiring heavy rains or abundant moisture (such, for example, as cocoa) are indicated. It seems probable that the natural vegetation has been considerably displaced by clearance for cultivation, but the land has been turned to farming only for the production of such crops as yam, cassava, some grains, etc., in this respect differing from the districts farther to the north.

Inland, however, the rainfall increases, to give rise to more normal equatorial vegetation. Rain-forest steadily becomes denser on low plain as on high plateau, thereby suggesting the convectional origin of the rains. But relief does seem to play no little part in determining the details of its distribution. Thus the Krobo uplands may be viewed as a barrier lying at right angles across the path of the south-west monsoonal winds which, it should be recalled, characterize these coast-lands in general. It is not surprising, therefore, to note how the rain-forest seems to be more especially dense over windward districts, while to the east and north, beyond the relief barrier, the change from rain-forest to park- and scrub-land seems to suggest a steady diminution in rainfall, such as would be experienced where a rain shadow occurs. Particularly in the districts J6–L6 and G7–I7 may it be noted how forest steadily thins eastward and dense tree-growth follows only the watercourses (perhaps where seasonally flooded), while in the neighbourhood of Akuse (H8) even along river-banks forest is replaced by bush and scrub.

South-east of Koforidua not only does the escarpment facing the Densu plains become lower in altitude, but a change in the nature of plateau relief also occurs. Whereas in north-westerly localities the plateau in general falls from summit altitudes of some 2000 feet slowly to the north-east, to give rise to a gradual transition in this direction from pure forest (portrayed by the uniformity of tree symbols) to mixed formations, yet on the other hand, particularly between Mangoase and Koforidua, the lower and more broken escarpment is simply a first step to the higher plateau of almost parallel trend, comprising the northern Akwapim uplands, which drop steeply to the eastern Volta plains. In view of the orientation of the latter ridges it is of interest to note how the distribution of rainfall may here again be modified by relief control, to cause a perpetuation—or even an increase—in the volume of rainfall as the higher plateau of the interior is encountered. Though it is, perhaps, dangerous to make a surmise from the evidence of the map alone, it might also be suggested that this district illustrates the fact

that rain shadow areas do not necessarily occur immediately to leeward of an upland crest.

Almost the entire Akwapim ridge (which extends south-westward) may be viewed as a unit which is transitional in its vegetation between the purer rain-forest of the north and the semi-arid coastal plains, for tree symbols are more widely spaced and denote mixed growth, while cocoa cultivation more generally has been replaced by the growth of oil-palms.

These two sheets therefore portray a complete sample of Gold Coast climates, ranging from the peculiar arid coastal plains through a belt of savanna forest and scrub—perhaps a zone of moderate rains—to the dense rain-forest, which finally in the north and east fades toward the region of lighter rains, on the interior open savanna plains. Finally, it should perhaps be borne in mind that deforestation may have occurred, to mask the natural vegetation—particularly likely where a region is by nature transitional between moist and relatively arid conditions. For example, the south-east Akwapim uplands are relatively densely populated, and have probably been long subjected to forest clearance. It is easy to imagine that soil-wash would be rapid where slopes are often steep; hence this district may to-day appear to be more lightly wooded than it was in its virgin state. The dense growth of scrub rather than forest—*e.g.*, in the neighbourhood of Aboasso (C4)—may indicate the nature of the vegetation which tends to replace true forest growth when the latter is destroyed.

But apart from this suggested modification, the probability of lighter rainfall over the south and south-eastern Akwapim plateau (as compared with that characterizing the north) is indicated with some certainty by the presence of oil-palms and farm-lands (for root crops and grains) rather than cocoa plantations. The distribution of the latter crop is of great significance in map-interpretation, for there are pronounced climatic limitations restricting its production far more closely than in the case of the oil-palm. Briefly, cocoa cultivation requires (1) a constant high temperature; (2) considerable moisture and a deep soil

(the relative humidity should in general lie between 89 per cent. and 80 per cent.; if it falls lower than 75 per cent. and exceeds a range of 9 per cent., then the crop will not thrive [1]); (3) an absence of direct exposure to the rays of the tropical sun—hence it is a crop especially adapted to growth within rain-forest clearings; (4) complete shelter from strong winds. Perhaps the most dense and continuous zone of cultivation is that which lies immediately to the south and south-east of Koforidua, on the forested Densu plains, and the north-west Akwapim plateau. Here the level nature of the region is likely to ensure the presence of deep soils, while the low latitude (6° 0′–6° 5′ N.) should guarantee high rainfall and humidity, the shelter of forest vegetation, and calms (characteristic of the doldrums), with small risk of the violent tornado winds which are common in more northerly latitudes, particularly at the change of the seasons.

But the farther one proceeds inland the more are cocoa plantations restricted to the immediate vicinity of water-courses, where presumably adequate depth of soil and moisture are attained. Their location—often in deep and relatively narrow glens—may reflect not only the decreasing amount of rain, but also perhaps the need to guard against the risk of exposure to stronger winds—it may be at times even to the dreaded Harmattan, though the latitude is perhaps somewhat low for this north-easterly wind to be felt to any appreciable degree. One must remember, however, that the restricted distribution of plantation crops is very often dependent upon social rather than climatic factors, particularly in regions as yet but thinly occupied; and, as will be discussed later, the location of plantations may equally result from the requirements of villages, or tribal custom, or the degree to which forest penetration as yet has been possible.

Quite apart from a consideration of vegetation in relation to relief and climate, it is of great geographical importance to note how far conditions may seem to be favourable for the breeding of particularly obnoxious pests, for the liability of a district to tropical diseases is a factor often equally

[1] Dr T. F. Chipp, *The Forest Officers' Handbook of the Gold Coast.*

important with—if not more important than—direct climatic or topographic influences in modifying the human response. For example, there is great need to estimate the liability of a district to the inroads of the tsetse-fly, for the latter may in some cases cause the decimation of population through sleeping sickness or, in other circumstances, restrict or entirely negative pastoral development within the localities affected. It may not be inadvisable, therefore, to enumerate the conditions of habitat which are especially favourable to the more dangerous species.

The blood-sucking tsetse-flies (*Glossina*) include a variety of species, of which two groups particularly are of importance —namely, *Glossina palpalis* and *Glossina morsitans*. The former is especially associated with the transmission of sleeping sickness and the latter with cattle sickness. The two groups do not flourish under identically similar conditions. Though to varying degrees all tsetse need some shade and a certain measure of protection from strong wind, there is a distinct contrast in the humidity of the air and degree of exposure to the sun which each type will tolerate.

Glossina palpalis is definitely restricted to the close proximity of rivers, streams, and running water. Dr A. P. Hodges considers that "the smallest trickle of forest stream is more likely to harbour the fly than acres of stagnant swamp or miles of swamp-choked river."[1] Where mangrove swamps are encountered, however, the species is likely to flourish.[2] The *palpalis* group, furthermore, is closely restricted to regions of intense shade (such as are provided by mangrove swamps or forest), and therefore the species is not found in tracts of open grassland. The fly is yet further limited to low altitudes, and has not been found above 4000 feet. From these facts it is possible to suggest several districts which might be liable to sleeping sickness. For example, the coastal plains east of Accra in general could scarcely provide favourable haunts for the fly, since the district comprises

[1] Reports of the Sleeping Sickness Commission of the Royal Society, vol. ix, 1908.

[2] J. J. Simpson, *Bulletin of Entomological Research*. vol. ii, p. 220, May, 1911.

quite open plain and cleared scrub, and seems definitely to be a zone experiencing low rainfall. But especially to the north, in the belt of rain-forest, the plateau is dissected by many small, narrow valleys, which, together with considerable sections of the main watercourses, would provide the requisite degree of calms, shade, high humidity, and proximity to running rather than stagnant water. Close riverside settlement in these districts might certainly involve contact with the transmitter of the dread disease. It is interesting to note the occurrence of the word 'tsetse' in place-names—*e.g.*, Tsetseku (I4).

Glossina morsitans, responsible primarily, though not entirely, for the transmission of cattle sickness (*nagana*, etc.), is not restricted so closely in its distribution either topographically or climatically. It requires some shade, but, unlike *Glossina palpalis*, not necessarily dense shade, and therefore it may be found where vegetation provides "moderate but not excessive cover." Furthermore, *Glossina morsitans* is not nearly so closely restricted to the immediate neighbourhood of running water, nor is so high a degree of relative humidity essential, while, again, it may exist at much greater altitudes. The fly has therefore a wider distribution, and may occupy belts of savanna some distance from running water. *Glossina morsitans* is far less susceptible to exposure to the full tropical sunlight, though *Glossina palpalis* is in this way easily killed. Therefore the fly belts of *Glossina morsitans* are most likely to exist "in thick bush and scrub near isolated clumps of trees and thickets with dense undergrowth, rather than along the banks of rivers in dense forests."[1]

A final characteristic (and one of some importance from the point of view of map deductions) is the tendency of the flies to occur in definite fly belts, a phenomenon which is especially pronounced in the case of *Glossina morsitans*. Though many localities may appear to be eminently suitable for the breeding of the pest, it by no means follows that the fly frequents these districts, for within a whole fly zone the actual distribution occurs only in patches or belts, which

[1] F. W. Cragg and W. S. Patton, *Text-book of Medical Entomology*.

shift in position seasonally (according to some, though not all, writers, with the migration of game—the likely host).[1]

Beyond the fly belts *Glossina palpalis* is found not farther than fifty yards, while the whole fly range seldom exceeds a distance of 300 yards from water. *Glossina morsitans* may, however, be encountered somewhat farther beyond the normal bounds of the fly zone; indeed, as has been said, the general distribution of this species is far less rigidly restricted by the control of climate, vegetation, or topography.

We have diverged at some length from the question of map-interpretation because a knowledge of the above facts is essential if one is to guard against hasty generalizations or faulty arguments about an aspect of the tropical environment which may be of very great geographical significance. Applying the facts to the region under discussion, we may suggest that *Glossina morsitans* does not frequent the plateau rain-forests or the Densu rain-forests to the west. But the more thinly wooded uplands of the Aburi Addukrum ridge, and the foothill zone to the south, may represent infested districts. It may be noted that the foothill zone is a region possessing both an adequate water-supply and a growth of savanna forest that is moderately thick to dense—hence there is sufficient shade. But over the exceptionally open coastal plains—almost devoid of tree or bush—it seems probable that fly belts are absent.

It is impossible to find any criterion which could be used to delimit fly zones more precisely. In the early stages of colonial development, before the advent of motor-transport, the character of communications might have afforded a use-

[1] T. Barnes, in *The Gold Regions of South-east Africa* (London, 1897), says: "The fly is extremely local, and extensive districts in which it prevails may be passed through by the aid of guides who know the patches of fly just as the pilot knows the shoals of an estuary, but it shifts with the migration of game, and therefore the knowledge of the guide should be recent." On the question of fly belts see also Cuthbert Christy, "Tsetse Flies and Fly Belts," in the *Annals of Tropical Medicine and Parasitology*, vol. xi, 1918. Many other writers record that it is possible to take cattle through broad fly belts practically with immunity, provided that the traverse be made upon a dark night, the cattle resting by day in open or cleared patches of scrub, where the absence of shade and moisture renders the halt free from flies.

ful clue, since the European changed his mode of transport from saddle to hammock on entering a fly zone, and it may be noted that the map symbolism does differentiate the road from tracks suitable for hammocking. The fact that a road runs from Aburi to Apirrade (G6–E4) is sufficient comment on the inutility of this line of evidence to-day, when it is known that "it is certain death to take a horse to Aburi"![1] It is possible, however, that anomalous and otherwise inexplicable bends in main roads may result from the advisability of skirting rather than crossing any well-defined fly belt.

In the plains west of Akuse and Kpong (H–G, 7–8) there seems almost a phenomenal absence of farms, attempts at forest clearance, and native paths and tracks—features of especial note when this region is compared with the coastal plains east of Accra. It seems therefore not unreasonable again to surmise that at least the shaded watercourses and thin savanna forest may provide shelter for the tsetse.[2] Again, it may be noted that west and north-west of Accra, beyond a radius of from 4 to 5 miles, the settlements tend to thin considerably. Unlike the Aburi uplands to the north-east, the extension of the ridge from A2 to B3 is marked by no village settlements or farm clearings, while along the Densu (whose immediate course seems to be bordered by wood and thicket) habitations cluster in every case some distance from the valley bottom—doubtless in this way avoiding the floods of the wet season, but perhaps also the riverside limits of a *Glossina palpalis* fly zone. There are few roads in this region; indeed, the coastal route, elsewhere more or less continuous, is here marked only by a telegraph line, no longer bordering a road—*i.e.*, through the uncleared belt between Oblogo station (A3) and Ajase (A1). In view of the above characteristics portrayed on the map, it is interesting to note that Simpson[3] records the existence of a fly belt of the *palpalis* group at a distance of from 5 to 12 miles from Accra, definitely noting species from the

[1] Mary H. Kingsley, *Travels in West Africa*.

[2] Dr Simpson records *G. palpalis* in the district of Kpong and Akuse (*Bulletin of Entomological Research*, vol. v, 1914–15), though specimens had not then been caught from the plains behind.

[3] *Op. cit.*, vol. v.

district around the Weshiang waterworks (A2) and northward to Nsawam (D2), and he has suggested the possibility of the fly infesting the whole Densu valley, at least up to Nsawam.

Human Geography and the Major Natural Regions

In dividing the area into natural regions it is necessary to bear in mind all previous deductions as to relief, climate, and vegetation, considered now especially in relation to human activities. Four major provinces may be recognized, each possessing some measure of physical and climatic unity and a certain identity of human interests, though in no case are they bounded by sharply defined frontiers. They comprise the following districts: (1) the Krobo plateau, together with its continuations northward and eastward as far as the sheet margins; (2) the Akwapim uplands, including the Aboasso-Apirrade higher plateau (C4–G6); (3) the broad Densu basin and plains, approximately north-west of Mangoase (F3); (4) the coastal plains south of the Akwapim uplands, together with the plains of the lower Volta (as far as these are shown on the present map).

(1) **The Krobo Plateau.** This is the plateau north of I1–7 and south-westward as far as the line of the Safo-Osubitru streams (G4 and 5).

Physically this region consists of a plateau whose elevation varies from heights of moderate to considerable altitude. It drops by alternating scarp and gentle terrace to the north-east, and the main lines of drainage follow the same direction.

Climatically the region seems to be one of normal subequatorial type; vegetation grades steadily from pure rainforest north-eastward to thinner mixed forest, and finally to the savanna growth characteristic of interior plains.

In its human geography this province differs from adjacent regions from the point of view both of types of distribution and of the major interests of the occupants. As a whole the population is relatively unevenly distributed, and not of great density. Settlement is densest toward the east, where

communities form long, straggling lines threading through the forest. Apart from the centre of Begro, the bulk of the villages lie in the area demarcated within K5–J5—*i.e.*, to the leeward side of the uplands, on the margin of the belt of heavy rains, and therefore perhaps where the associated high forests begin to fade toward thinner mixed formations. The persistence elsewhere of topographic and forest divides leads one to suspect that these forest settlements may have resulted from relatively recent infiltration under pressure from the north-east—a region of lower plateau and more open tree-growth. This surmise is to some extent supported by the form and the gradation in size of the villages on passing westward into the deeper forest shades.

The province as a whole might be viewed as one which portrays the sub-equatorial forest-dweller at a phase of transition from the stage of *collecting* both wild and cultivated forest products purely for his own requirements to that of *plantation cultivation* primarily in relation to the economic interests of an outside power. But the western and eastern sections of the plateau portray noteworthy contrasts in the stage of transition reached, and these are typified by the small township settlement of 1000–5000 inhabitants at Begro (K2) (which, incidentally, is the only centre of consolidated form in the whole province, and the single focus of settlement in the western plateau) and the Dawa Mate Kole district, to the east (J5).

A study of the district around Begro is of particular interest because of the isolation of the site from neighbouring plateau centres for so considerable a distance. This renders it possible to identify somewhat more clearly than farther to the east the extent of the forest area which the one community develops and upon which it depends, as well as the probable character of the yearly cycle of activities.

In site Begro profits (probably from the point of view of health equally with strategy) from the advantages of a hill-top position on a small, isolated plateau spur; yet at the same time it lies almost in immediate contact with a supply of pure water, obtainable from the heads of many adjacent streams. Not only, too, is there relatively easy access *via*

the broad valleys to adjacent stretches of plateau forest, but furthermore to the west the escarpment edge in this district slightly falls in altitude, to render contact with the western plains easier than it is for some distance to north and south. From Begro, the focus of settlement, no roads, but innumerable paths and tracks of varied types ramify in all directions. A knowledge of the habits of equatorial forest-dwellers in general suggests the probable purpose of the habitations to which the paths lead. It is possible, for example, that the tracks ramifying out to isolated farm huts[1] or to small groups of habitations some distance from Begro are the routes used (perhaps but seasonally) by the farmers responsible not only for the produce of the few cocoa plantations (probably but recently developed), but also for the food crops grown in forest clearings for the community in general. (Note in this connexion the many scattered farms of the Akwad uplands.) The small group of habitations at Jukwa, placed close to the stream, suggests another seasonal movement common to many forest peoples. Though the habitations may be used primarily by the farmers tending adjacent cocoa plantations, yet they may also be used at suitable seasons by quite a considerable number of the inhabitants, who may come to the streams to collect a harvest of fish. Perhaps of greatest interest are the trails[2] leading far afield to the solitary hunter's camp or rubber collector's shelter (symbol 39). The map portrays the way in which these trails thread the remoter and isolated depths of the forest in country seemingly of impassable virgin forest. These are associations peculiar to this district.

The triangle of plateau (L–J, 1, 2, and 3) may therefore be described as a unit where there is mingled both sedentary and semi-nomadic life, in a manner characteristic of human societies of forest lands in an era of transition.

With the exhaustion of adjacent districts, farms and camps will be moved yet farther from Begro, and temporary migrations perforce will become of longer duration. No other settlement can claim to a site so isolated, whether by relief

[1] Note symbol 39. Distinguish this from symbol 81.
[2] Symbol 64.

or vegetation, and, significantly, elsewhere at no other centre does there seem definite evidence that the collection of the natural wealth of the forest still prevails to any appreciable extent. It should be noted, however, that Begro is connected with Osino, a centre on the railway and road highway to the west; but all produce taken down to the plains must be transported by means of the carrier, with his headload of some sixty pounds, for not even a pioneer road as yet penetrates the plateau in this district.

East of the river Akrum somewhat contrasting conditions are present. Here the plateau is lower in altitude and characterized by thinner tree-growth, while settlement is correspondingly denser. It seems clear that the village settlements have grown along the lines of forest clearings. Habitations follow the valley-side, forming units distinctly reminiscent of the 'street villages' which have been identified in both mountain forest clearings (see Map XVI) and marshlands (Map XXIII). We can readily appreciate the importance of the valleys in providing lines of easiest access into the heart of the plateau—not because the streams provide opportunity for water-transport (stream volume is far too small and variable, while gradients in general are steep and irregular), but because settlements are here assured an adequate supply of pure water, sufficient for all native requirements. Reconstructing a picture from the map symbolism, we can imagine the low and often dilapidated dwellings of the larger valley villages, built doubtless from the flimsy forest material to hand, in straggling succession, insignificant, and often invisible in the deep shade of the vast and dominating forest superstructure. In completing the picture we should notice how it is a site on the valley flanks rather than on the valley floor which is generally utilized; in this way habitations presumably avoid the rising floods of the rainy season, or the excessively humid air and unhealthy conditions which may prevail nearer the floor of the glens.

In contrast to the sparsely settled western plateau, the eastern seems to be one where the production of plantation crops is dominant, leading in general to a more sedentary occupation of the soil. Everywhere villages seem to lie in

close proximity to cocoa plantations, the extension of which seems very probably to determine the rate at which forest penetration and settlement proceeds. Already it has been suggested that the relatively deep valleys dissecting the plateau possess many characteristics especially suitable for cocoa production; and it may be remembered that it is in the immediate vicinity of streams that first seed-beds are generally planted. The form and distribution of villages may therefore in no small measure be related to these facts, which account for the situation, especially in the interior, of plantations and villages together in the valleys. The few farm huts (symbol 39) which generally occur in the neighbourhood of village or plantation remind one of the need to cultivate some other products to meet the food requirements of the population. As one passes southward the cocoa plantations increase in acreage to a truly remarkable extent, in some districts entirely replacing vast stretches of forest, with the result that there is a strong tendency toward the dangerous economic practice of dependence on monoculture.

The system seems the more unusual when one reads the map evidence of plantation cultivation under native superintendence and by native methods, with the minimum of white supervision. This, for example, explains the many instances of plantations in forest clearings quite remote from villages or even single habitations, suggesting the dilatory native methods whereby plants are left to yield as they may, receiving little or no attention once planted in a clearing.

In addition there is clearly very little direct contact with the European, as shown firstly by the complete absence of pioneer roads (symbol 61c)—still more of motor-roads—over very large sections of the region. Secondly, unlike most other districts, even missionary influences seem here to have penetrated but slightly. Westward of Anyaboni, Adefa, and Apinsu (0° 5′ W.) there is an absence of mission houses until Begro is reached. (Compare this with the frequency of missions to the south.)

Two other features are of interest in illustrating the character of native life—namely, the distribution of markets and of chiefs' houses. The frequency of the market in this region

(as elsewhere over the whole area portrayed on the map) is perhaps somewhat surprising. A number of quite small village centres, each possessing a market, replace the single regional market town with which we are more familiar (note the letter M, symbol 24). This fact suggests firstly the relative isolation of these settlements (it may be difficult to traverse the intervening forest—hence the need for many local markets), and secondly the special function of numerous local markets in the transitional period of colonial development. For the direct contact of the colonist with the native is preceded in many equatorial regions by a stage when natives themselves act as trading intermediaries, collecting supplies of European goods, which are used at each local centre as barter for forest products. The development of communications renders the native middleman unnecessary, and it is perhaps the more likely that this relatively isolated unit, as yet so deficient in made roads, may still depend upon the native trader in this way. Doubtless the development of railways to the west and of roads leading up from Koforidua is bound to cause considerable changes. Innumerable paths of the type "fit for hammocking or *for carriers with loads*" (symbol 62) suggest a picture of lines of carriers, each perhaps with a load of some fifty to seventy pounds of cocoa beans,[1] threading the shade of the forest to the nearest road or railway loading-station.

According to the map, a chief's house is not present within every village or smaller group of dwellings. This fact suggests two characteristics of the probable social and economic organization of these forest-dwellers. In the first place, groups of habitations which do not possess a chief's house may simply mark sites frequented only seasonally—a likely occurrence, since plantations often lie some distance from the villages. It is obvious from the map that even when crop cultivation replaces simple forest collecting a considerable degree of seasonal nomadism must still prevail, owing to the primitive and wasteful methods which result in the very rough clearance of fields at successively more distant localities as soil exhaustion takes place. Some of the

[1] The normal headload weight in this region.

smaller centres may mark the first stages in the growth of a new village, preparatory to the advance of the whole community to new clearings. But the absence of a chief's house might perhaps be interpreted in another way, as a means of identifying the organization and conditions of land tenure which are present in the colony. It may be stated as a general rule that the farther one penetrates toward the interior plateau forests, the less frequent do chiefs' houses become—even in quite large villages they are absent. (Note the many villages without one within the area J4.) These villages may represent (indeed, their position also suggests it) territory which has been occupied but recently, and where as yet the village community has not become greatly enlarged by the addition of members from numerous other families. For the head of a village is usually the founder or the present head of the family first responsible for forest clearance (and hence land ownership), and he is assisted by a council comprising the heads of new families which have since joined the community.[1]

As at first defined, the boundary of this major natural region is extended south to the line of the Osubitru-Safo streams, because the economic interests of the inhabitants remain unchanged, though the plateau and scarp south of Koforidua fall considerably in altitude. It is here (G4 and 5) that cocoa cultivation seems to attain to its maximum intensity, diminishing toward the north—perhaps the direction in which the industry has spread, and is still spreading. The two rivers (Osubitru and Safo) mark a change, however, in the vegetation, for south of this frontier the cultivation of oil-palms replaces that of the cocoa bush—which latter immediately to the north of the boundary extends continuously for mile after mile, no longer restricted to valleys or to sites adjacent to running water. The abrupt change in the economic interests of the inhabitants, with a corresponding change in the distribution of population and the form of the villages, is sufficient reason for this suggested delimitation of the boundary of natural geographical provinces.

[1] See J. M. Sarbah, *Fanti National Constitution* (1906) and *Fanti Customary Laws* (1904).

(2) **The Akwapim Plateau.** This province (south-east of that described in (1) above) merits separate consideration firstly because of its distinct relief, as a much lower plateau, now orientated from south-west to north-east (rather than from north-west to south-east as is region (1)), and secondly because it comprises a zone of different climate and of contrasting vegetation, transitional in type between the plateau to the north and the coastal plain to the south. The change in the vegetation may be due partly to relief, for the ridge now runs parallel with and not transversely to the prevailing south-west monsoon winds, and therefore rainfall will be so distributed as to lead to no pronounced windward and leeward aspect. But also it may be determined by artificial interference—*i.e.*, by deforestation for cultivation.[1] But whatever may be the cause, the important geographic fact remains that the cocoa production is replaced by that of the oil-palm—*i.e.*, the cultivation of an indigenous rather than a foreign plant prevails in this province. It may be remembered that before the development of the cocoa trade the oil-palm provided the most important vegetable industry of the Gold Coast. This fell before the new product, which called for smaller expenditure of energy and yet gave better payment. In some districts the continued rival importance of the two industries is suggested by the very close mingling of the symbols denoting them, especially over sections of the plateau near the boundaries of provinces (1) and (2).

The villages which are located on the Akwapim Hills provide a striking contrast in form to those of the northern forests. From Kunkunu (D4) to Apirrade (G6) there extends a series of consolidated foci. Aburi, typical of the region, may be contrasted with Awawasu (K5–L5). The gravitation of centres to the one ridge seems to suggest that some particular advantages occur here. Certainly the ridge

[1] That considerable changes are due to deforestation in this locality does seem to be the case. It may interest the reader to know that the great cocoa industry of the colony spread from the village of Mampong (E5). Here in 1879 a native planted a few cocoa seeds brought into the colony. One tree was successfully cultivated, and from this beginning the whole industry has grown, though it is clear from the map that it has shifted distinctly to the north.

occupies a position which is transitional in climate, vegetation, and altitude between the semi-arid coastal plains to the south and the densely wooded interior plateau previously described.

It may be that here, at least a 1000 feet above the coastal plain, some advantage could be obtained from slightly lower temperatures, associated, too, with a rainfall which is neither too heavy nor too light, as in the case of adjacent areas. Especially important in relation to early native settlement may have been the fact that in this district the oil-palm seems to grow prolifically, so that the uplands lie flanked on either hand by strongly contrasting environments, of lesser economic value as measured purely from the standpoint of native interests. For the oil-palm is a product of inestimable value to the African in supplying palm-wine, oils, foods, building material, thatch, etc.

Perhaps, too, in historic importance provinces (1) and (2) present contrasts. Certainly the stages of colonial development attained to are by no means comparable. European influences have penetrated deeply into the small townships of the Akwapim ridge. In every centre the chief's house and the local market stand side by side with mission house or church, with the addition in some cases of court houses, rest houses, and post and telegraph offices, while the chief centres are all united by roads generally suitable for motor-traffic throughout the year (symbol 59) and—at least as far as Akropong—by telegraphic communication! In the Krobo plateau no village has become the centre of a head chief, but Akropong, in the Akwapim Hills, is a village of this rank[1]—perhaps because of its position on the favoured ridge where this not only rises to an altitude of 1450 feet, but also adjoins the contrasting forest environment to the north.

The constructive nature of our colonial policy is revealed not only in the development of roads and of telegraphic communications, but also in the creation of agricultural stations—*e.g.*, at Aburi (E4).

(3) **The Upland Plains.** These lie roughly north-west of Mangoase. At least from the point of view of vegetation

[1] Identified by the underlining of the name in red (see key).

and of cultivation this region might well have been considered together with province (1), but there are pronounced contrasts not only in average altitude, but also in topographic detail. Furthermore, there are important differences in the general character of the settlements and the degree to which foreign influences have penetrated, so that the region on these grounds merits separate consideration. Apart from the fragments of dissected plateau whose form has already been noted, we may regard the region physically as a plain of relatively featureless relief. Tributary streams, separated from each other by no pronounced divides such as occur on the Krobo plateau, drain the open plain in dendritic pattern, uniting to join either the river Densu or the Birrim system north-west of the low divide at I1.

In one respect the natural vegetation of this unit may differ slightly from that which characterizes the escarpment and western borders of the plateau within province (1). The latter is clothed with pure rain-forest (as gauged by the type of tree symbols), whereas on the Densu plains it is mixed bush and forest which flourishes. This perhaps is to be expected if rainfall increases in passing over the windward ramparts of the western plateau margin. In the economic development of the region two contrasts become especially clear. First, the leading plantation crop (as perhaps would be expected) is cocoa, but the plantations are no longer closely restricted, since in this locality the youthful valleys which characterize the Krobo plateau do not occur. Cultivation has therefore become far more widespread. Secondly, oil-palms tend—as in province (1)—to replace the cocoa plant toward the south; but in the upper Birrim valley (6° 15′ N.) there are indications of the development of yet another equatorial product. Over an area of about 1 square mile rubber plantations—*i.e.*, for the cultivated product—are established (symbol 77). This fact summarizes the nature of the contrast in the stage of development of plateau and lower plain, for whereas it is by the collection of the wild product and subsequent carriage by head-porterage to the nearest market that the product is exported—if at all—from the district of Begro, it is by motor-road or by railway that

the cultivated plantation crop is exported from the Birrim valley.

The chief settlements are of consolidated form, and are concentrated along the foothills immediately in front of the plateau. Some of the advantages which may have determined their location can be suggested from the map. Firstly, they lie at the point of contact of two natural regions, and, secondly, are on sites which are well drained. The importance of the last factor is suggested by the marked way in which not only large centres, but even isolated farms and small settlements tend to seek out any minor eminence—no matter how small the knoll may be—in order to avoid the flat plains of the western Densu. A third factor may be the need to ensure an adequate supply of *pure* water. According to the map this should—and apparently does—encourage firstly more concentrated settlement in the eastern Densu basin, where tributaries are far more frequent than to the west, and secondly the growth of villages near the sources of streams.

A comparison between Koforidua and Taffo brings out the fact that in one case it may prove advisable for the British settlement to utilize the immediate site of the native centre already established, in the other to develop one of their own. Old Taffo (I2) is clearly a native village—perhaps of early foundation—and a centre on which many minor roads focus from all directions. New Taffo seems to represent the new British centre; it is of regular plan and threaded by metalled roads, and placed on the railway some 2 miles from the older village. The population of the native village (attaining to some number between 1000 and 5000) may be contrasted with that of the new station, as yet counting not more than 1000 souls—it may even be but 200.

Koforidua by contrast is not only the town of a head chief, but also the provincial headquarters for British administration. The dominant factor which probably determined the growth of the native capital has doubtless also especially favoured the location at this position of the focus of administrative and economic development. For not only is Koforidua a foothill station, possessing all the advantages

which this implies, but it is also a definite route junction, since roads fork from it, one rising to penetrate into the heart of the plateau by the single deep valley which breaches an otherwise continuous escarpment rampart. But the map portrays by the presence of symbols 20 and 40 how complex and conflicting are the influences affecting the native outlook during the present era of transition; Koforidua is not a centre where native and British activities alone are mingled.

Z marks the settlement of the Hausa, or of other similar 'foreign' African races. The Hausa is an active trading intermediary for the native in many districts, and it is significant that the symbol denoting his quarters may be identified at intervals along the more important trading highways of the whole region. From the evidence of the map one would suggest that the degrees to which Hausa and British influences have penetrated contrast very strongly. To a certain extent this can be measured by the spread of the Moslem and of the Christian faith, each seeking to gain adherents from among the native fetish-temple worshippers (symbol 21). Protestant mission stations and churches occur in great profusion—in some cases in seemingly inaccessible districts—but the mosque is found only at Koforidua and New Taffo, in spite of the considerable number of Hausa *zongos* (settlements) which occur in some districts.

(4) **The Coastal Plains.** Physically this is a unit of low altitude, except where it is diversified by relics of dissected plateau. To the peculiar climate of the region one may probably attribute the contrast between the human occupations within this region and those of adjacent areas, for the low rainfall seems to have prohibited the development of a plantation crop. Over a plain clothed but thinly with bush or scrub, farms devoted to the production of yams, cassava, grain, etc. (symbol 81), occur at intervals. Except toward the west, there is no oil-palm cultivation, and, as would be expected, cocoa plantations are absent. The region therefore presents as marked a contrast economically as physically to the remaining provinces.

Occasional clumps of trees (see D5) suggest that woodland

originally may have been far more widespread; it may be that these remaining woods have escaped the seasonal fires (started both by accident and design) by which land is so often cleared of the coarse scrub growth in readiness for cultivation. The question arises as to how far the more definite forest growth as opposed to scrub growth in the Volta plains is a result not perhaps of slightly increased rainfall as compared with the plains to the west, but of the preservation of the natural vegetation, elsewhere altered or modified in character by prolonged deforestation. This of course cannot be discovered from the map.

The whole district, including both the plains of the Volta and of Accra, shows a distinct marginal concentration of settlements in two belts, one coastal, the other inland—*i.e.*, following the boundary of this natural region to both north and south. Between the two belts settlement is extremely sparse or non-existent. The region affords an interesting comparative study of an equatorial coastal region where the distribution of population is especially related to a search for an adequate supply of water, and may therefore check the conception sometimes prevalent that regions of low latitude are invariably characterized by the growth of luxuriant vegetation and by heavy equatorial rains.

Westward from Kpong (H7) villages and markets border the Akwapim Hills, profiting by a position on the richer soils (which one presumes to be present), accumulated as cones flanking the base of the ridge, and, also, by situations where streams either take their rise or as a result of the abrupt change in gradient, spread out and become partially absorbed where they cross the alluvial fans. The preference for a foothill site is particularly evident in the Volta plains; the villages and farms, surrounded by oil-palm plantations, occur only in this position. Linked by a motor-road, they have grown especially where wells can guarantee an adequate water-supply at all seasons (note the frequency of wells along the upper Sankado (H6)).

Akuse is the only centre placed some distance from the foothill zone. It is not possible to identify from these two sheets all of the factors which have determined the import-

ance of the site. Akuse is obviously the collecting centre for the produce of the foothill villages, to which it is linked by both metalled road and telegraph. Particularly when adjacent sheets are studied, its importance becomes clear as a riverside collecting centre at the limit of navigation, before entering, upstream, the braided reaches of the river at Kpong and the clearly restricted channel (with presumably rapidly flowing water) above Kpong, where the Volta has cut a gorge transversely through the plateau.[1] The contrast in the outlook of European and native interests is suggested by the fact that though Akuse is the provincial capital for Europeans (*i.e.*, marked as "headquarters"), Akropong is the *native* capital (*i.e.*, the town of the head chief), in this respect contrasting, therefore, with Koforidua, the combined centre for British and native rule.

The plains of Accra portray a similar concentration of settlement where water-supply and soil fertility can be most surely guaranteed. The difficulty of supplying sufficient water for an urban centre and European requirements is exemplified in the case of Accra itself, which is apparently supplied from waterworks erected on the nearest river of considerable volume and at that part of its course where most suitable conditions obtain for the construction of a reservoir—*i.e.*, practically within the shelter of the gorge where the Densu breaches the last fragment of the Akwapim plateau (A2). These works are linked to Accra by a light railway.

East of Accra there seems proof of a decline in land values, for many of the very small villages and also individual farms are marked as deserted (see particularly C–B, 5–6). This may possibly indicate exhaustion of soil and migration of cultivators to newer fields—a common practice in regions of primitive, non-intensive agriculture. It is interesting in this connexion to notice the greater frequency of farm-houses, farms, and hamlets within the Densu basin to the west. (Note the presence of both symbols 81 and 39.) But this may not be the only explanation of village desertion.

[1] Actually Akuse is an important collecting centre for the export of oil-palm.

It might equally be due to the exhaustion or diminished flow of wells and rivers—perhaps in part resulting from deforestation, for minor changes in the volume of rivers, or in the degree to which these are silt-laden, might easily result from this influence, and quite small changes of the kind are of the greatest moment in a region already suffering from a deficiency in the water-supply. Again, it may be that the greater economic attraction of cocoa cultivation has led to a partial depopulation of the plain as occupants withdraw inland to the more certain yields of the Akwapim uplands. Yet again it may be warfare and pressure from the north and east which has led to the desertion of the district. From the map alone, however, it is quite impossible to say which, if any, of these suggested causes have been operative. We can only surmise that the underlying influence may be the control of climate, for a slightly increased rainfall—presumably assuring greater soil fertility—would lead to a far less pronounced deterioration in soil values in this region.

In their relation to the Densu the two inland centres of Nsawam and Adwajere compare with Kpong on the Volta, since they all hold the opening of a gorge cut by their respective rivers through the upland barrier. Between the Volta and Densu it is likely that most of the coastal streams become of extremely small volume or dry up completely during the 'winter' dry season.

Lastly we may turn to the one remaining belt of settlements, flanking the shore-line itself, typified by the villages and scattered dwellings in the neighbourhood of Labadi, Teshi, Nungwa, and, finally, Accra itself. Some attraction has obviously drawn the population to the shore-line, and presumably these villages may be coastal fishing centres, dependent upon the fisheries of both sea and lagoons. (Fishing settlements of this character are present along many sections of the Guinea coast.) Furthermore, there is evidence of the growth of the coconut along the immediate shore where cliffs are absent or are under 50 feet in altitude—*i.e.*, where it seems probable that broader stretches of sands or sandy soils guarantee the occurrence of a suitable habitat.

Cultivation of the coconut (symbol 84) may provide an auxiliary industry for the coastal fishing population, since it is a crop which, at least at present, is located only along the immediate shore-line, and one that, together with dried fish, might provide the basis of a welcome exchange of produce with inland farmers.

Accra is the chief centre of the plains—indeed, of the whole district shown on these two sheets—for it is, as may be recalled, the capital of the colony. From here pioneer or metalled roads and railways ramify out along the chief highways of settlement; to this town there focuses and drains the produce of the remoter interior. The lines of British penetration to both north-west and north-east across the coastal plain are again frequently punctuated by Hausa *zongos.* When these quarters occur in proximity to native centres they are placed outside rather than within the village. They are, however, by no means restricted to populous districts, but occur in quite isolated situations—as, for example, along the route of the single-track railway and the telegraph line, even where the latter is not followed by a road (A1–4).

As a European capital Accra most probably is not entirely of artificial growth, for it is a head chief's town, and may quite well have grown to its present size from the nucleus provided by a coastal village settlement, perhaps originally somewhat larger and more important than its neighbours to east and west. Traces of earliest European penetration are revealed in the presence of the castle and Christiansborg station at Accra, and of Augustinesborg fort at Teshi. These remind us of the nature of the first stages of contact, which were effected by means of the fortified coastal trading factory. But .the influences which helped to determine the rise of the British headquarters at Accra rather than at any other coastal trading base may at first seem a little obscure. Considered in relation to the interior, the site has obvious advantages as a collecting centre, for it stands on the coastal plain where this grades from very thin and arid farmland toward moister regions favouring oil-palm production. Furthermore, the belt of settlement which borders the Akwapim hills runs out to the coast in

this district, and in addition the broad, dry breach through this narrowed upland (C3) ensures ease of communication with the interior Densu basin by both road and rail.

But as a port—the especial need of the European trader—Accra seems to possess little advantage. Just as in the case of neighbouring villages (especially of Teshi), Accra stands on an exposed shore-line, partly cliff- and partly lagoon-bordered, and facing a submarine slope of extremely gentle gradient. Form lines interpolated for 5 fathom intervals clearly disclose the reason for the surf boat for which the district is notorious, and for the necessity for sea-going vessels to anchor in open roadsteads some distance from the shore. The map therefore emphasizes the serious restriction to the development of the export traffic of the colony which results from the presence of so harbourless a coast. But along a shore-line so generally deficient quite minor advantages would become of considerable importance, and, judging from the map, Accra seems to possess just that relatively slight asset which would turn the balance in its favour. For the town has grown around a sweep of bay—quite a minor cliff-bordered indentation of the coast, but one which faces eastward. It may be that the advantage of protection thus afforded from both the strong south-west Guinea Current and the south-west winds (which we know to characterize this district in general) has played an important part in determining the development of the site.

Viewing the coastal province in relation to the whole area under discussion, it may be suggested that in spite of its many adverse economic conditions, none the less perhaps the farmlands and fisheries of the plain fulfil an important *rôle* in guaranteeing a margin of 'home' food-supplies for the population of both cocoa and oil-palm districts to the north, where a minimum area seems to be devoted to the production of necessary food crops. Thus these four natural regions of such contrasting opportunity, production, and apparent value become interdependent and integral parts of a whole. But future progress may completely alter present conditions. Profound economic changes may sweep over the plains, transforming their character as remarkably as the

spread of cocoa-planting has altered the nature of forest cultivation. On the plains it must obviously be another crop which is developed. Sisal, the plant whose cultivation has made such rapid strides in other tropical regions (*e.g.*, East Africa), has already become established in a large experimental agricultural station some 4 miles north-west of Accra (0° 15′ W.), and its widespread cultivation, with all the attendant changes in the distribution of settlements, may be a matter of only a short time period.

The Gold Coast sheets provide an illustration of the truth that any map can of necessity portray only conditions that exist at a given moment of time—in this case a phase unusually transitory, embodying the abrupt contact of peoples at extreme stages in the scale of social development—the mingling of many influences from both east and west, together superimposed upon a native life which is the product of a relatively enervating environment.

Conditions in some respects comparable would have been depicted by the Romans had they made topographical maps of contemporary Roman Britain. It is interesting to conjecture what such a map might have shown. There would inevitably be portrayed a similar contact of the primitive and the cultured—Briton and Roman—and the same contrast between the size and probably the amenities of many of the Romanized cities and the native British centres. The extremes in the scale of civilization portrayed on Roman and Gold Coast maps would be of kind rather than of degree—the contrast, for example, between the wireless station (symbol 89) at Accra and primitive native settlements can be little more strik ng than would be the portrayal on the imaginary Roman map of, say, colossal Roman baths adjacent to purely British hamlets. In both maps the importance of the road would be evident as a medium of civilization, especially as regards economic and administrative development. The importance to the Romans of their great highways is more easily appreciated when one observes the exceptional value of roads in the Gold Coast district. The limitations to their extension, as set by forest and swamp or waterlogged territory, would probably have been as clearly

evident on the map of Roman Britain as on that which depicts the vicinity of Accra. Again, the Roman map would most likely have portrayed local regions of imitation—*i.e.*, regions where ancient Britons were engaged in the economic development of their own land according to Roman needs, but with little Roman supervision—just as in the plateau cocoa plantations, which in some cases seem so definitely to be remote from contact with British authority.

But in one important aspect map-reading would probably reveal a great contrast, for although the Roman occupation led doubtless to a great development of the economic resources of the country—comparable to that recorded on the Gold Coast map—yet this depended primarily on military domination, and it is certain that the map would have provided ample evidence of the fact, for even the present 1-inch maps mark the remains of countless forts, camps, entrenchments, etc. But this in no way applies to the map of the Gold Coast, except in so far as the old coastal fortresses are marked. It is essentially the penetration of an economic rather than a military rule that is portrayed here. And yet it is, nevertheless, the existence of the made highway, whether road or rail, which determines the degree of penetration. Therefore in the Gold Coast, as elsewhere, map-reading not only reveals evidence that in a given regional unit geographical values are changing with the progress of historic time, but also suggests that there may exist at the same time a repetition of historical phenomena, masked though these may be by geographical differences.

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APPENDICES

I

FURTHER NOTES ON THE SITE OF CARLISLE

THE analysis of the site of Carlisle inevitably is incomplete when based on map-reading alone, and these notes are included to amplify some of the facts recorded earlier.

The Eden basin as a whole is in many parts deeply covered by glacial drifts and alluvial deposits, but at Carlisle a low Triassic sandstone bluff gradually rises northward in the direction of the river valley, until at the castle site it drops steeply to the alluvial flats immediately beyond. Here the overlying drift deposits are comparatively thin. Though doubtless at one time steepened directly by river action, the bluff is not now directly bounded by a river to the north. But in any case the bluff could easily be steepened by artificial means in fortifying the summit.

The strategic advantages of the position seem to have been appreciated since earliest times. A rough stockade was apparently built by the Celtic Brigantes on the site later occupied by the Romans and still later by the medieval castle. At this point not only was there *ease* of defence on the rising spur above the waterlogged flats, but equally was there *need* for defence, for the site coincided both with the head of tidal waters on the Eden and also with a position where the river could easily be forded. A study of the old maps of Carlisle [1] reveals the former existence of an island in the river at about the position of the present Eden road bridge. The main channel of the river lay to the south of the island, and passed near to the northern end of the present Rickergate and George Street. The river was then very shallow; on a map made in 1684 the depth is marked as 3 and 4 feet. From medieval times to the early nineteenth

[1] Some of them are reproduced in *The Royal Charters of the City of Carlisle*, by R. S. Ferguson (1894).

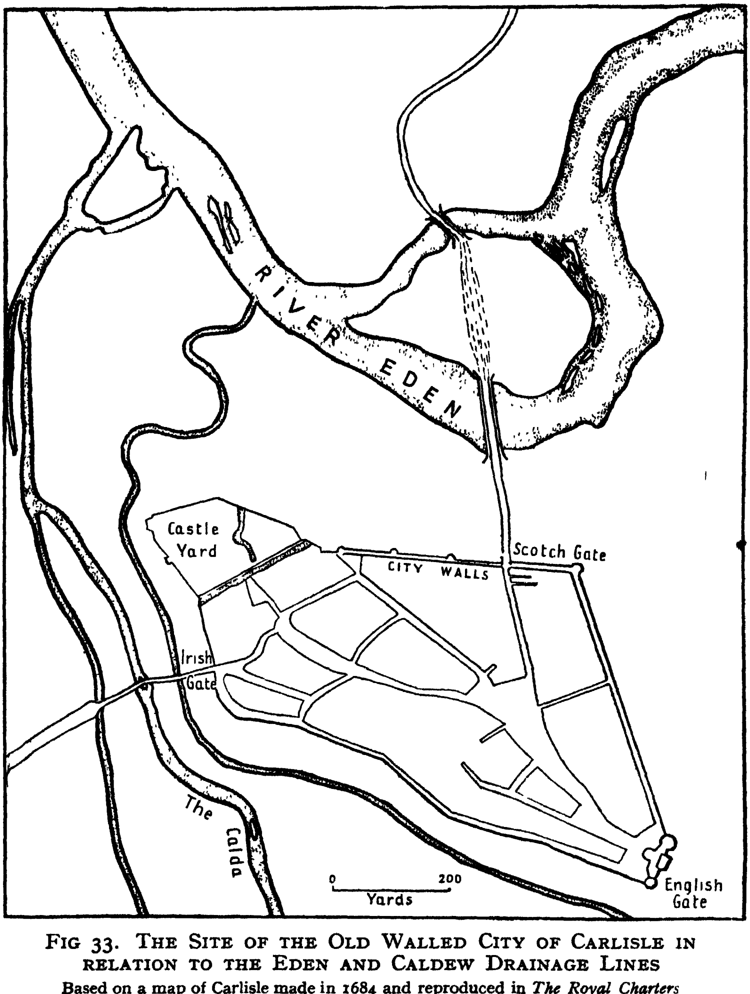

FIG 33. THE SITE OF THE OLD WALLED CITY OF CARLISLE IN RELATION TO THE EDEN AND CALDEW DRAINAGE LINES

Based on a map of Carlisle made in 1684 and reproduced in *The Royal Charters of the City of Carlisle*. Compare this with present maps of the city—published some 250 years later.

century the river was crossed by two wooden, and later stone, bridges. But in Roman times the crossing was effected simply by a ford and paved way (or *trajectus*), which led

from the Roman fort at Stanwix (probably on the site of the present village church) due south across the river and the island to meet the great south road terminating at the city. (See Fig. 33.)

The adjacent Eden flood-plain flanking the city to the north was also a most important strategic factor, for it was formerly much more marshy even than it is to-day. The so-called Castle Saucery represents the one-time *salicerie*, or willow-beds, which remained unreclaimed and undrained until the beginning of last century. The old Chronicle of Lanercost in describing Robert Bruce's attack and siege of the castle in 1315 gives an illuminating picture of the value of marshlands.[1]

Furthermore, the proximity of rich pasture land at the immediate castle and city gates themselves meant that cattle could easily be driven out to feed and brought back within the city gates during any lull in sieges or Border forays, while the guard kept watch over the very extensive region to be viewed from the castle and ramparts.

Not until the early nineteenth century was effective reclamation and embankment undertaken. Between 1812 and 1815 the southern channel of the Eden around the island was altogether eliminated, and the present stone bridge across the new single northern channel was erected. At the same time the Castle Saucery was reclaimed, and embankments were constructed to check inundations. These can be traced on the 1-inch map around the public park.

These modern artificial changes, not apparent to the map-reader, mask important one-time geographical factors which were of no little significance in determining the life and *rôle* of the city through history.

[1] "The King of Scotland, having gathered together all his force, came as far as Carlisle, and, surrounding the city, besieged it for ten days, treading down the cornfields and laying waste the suburbs and burning the whole country, and collected for his army all the cattle he could steal. . . . They erected a great engine for casting stones, and a great berefray in the manner of a tower. . . . But they never drew near to the wall, for when it was drawn upon wheels over moist and clayey ground there it stuck by reason of its weight, nor could it be drawn any further or occasion any inconvenience."—From a translation of the Chronicle of Lanercost, giving an account of the siege of Carlisle Castle in 1315 by the Scots with Robert Bruce.

II

TOPOGRAPHY AND INSOLATION

GIVEN accurate large-scale contoured maps, much can be determined regarding the influence of topography on the time period and the intensity of insolation in Alpine and other regions. Fig. 34 shows one of many types of maps that can be constructed to show the area of shadow for a selected day and hour—in this case at noon on midwinter's day. It is obtained by constructing a series of closely spaced relief sections drawn without exaggeration of the vertical scale and trending from south to north. On each section parallel rays are plotted according to the altitude of the sun for the hour and latitude (see Fig. 23). The series of points marking shadow boundaries are then transferred to each section line on the map, and are joined to delimit the shadow zone. The map illustrates a characteristic common in Alpine regions—viz., that above approximately 1100 metres permanent settlements tend to lie outside, or on the edge of, the area covered by the longest noonday shadow for the year.[1] It will be seen that Weissenried, the highest permanent settlement in the valley, occupies a position[2] outside the shadow, and has a more favourable site than the smaller hamlet of Ried—important chiefly for its hotel as a climbing centre for the Bietschorn. Again, Eisten is the last *permanent* hamlet up the valley. Other centres above this, and within the winter noonday shadow area, are used as summer settlements only.

Details of topography, again, determine the *intensity* of insolation—a feature that can be calculated by careful map-

[1] For further examples see "Insolation, Topography, and Settlement in Alpine Valleys," by A. Garnett, in the *Geographical Review*, vol. xxv, Oct. 1935.

[2] See pp. 168, 169.

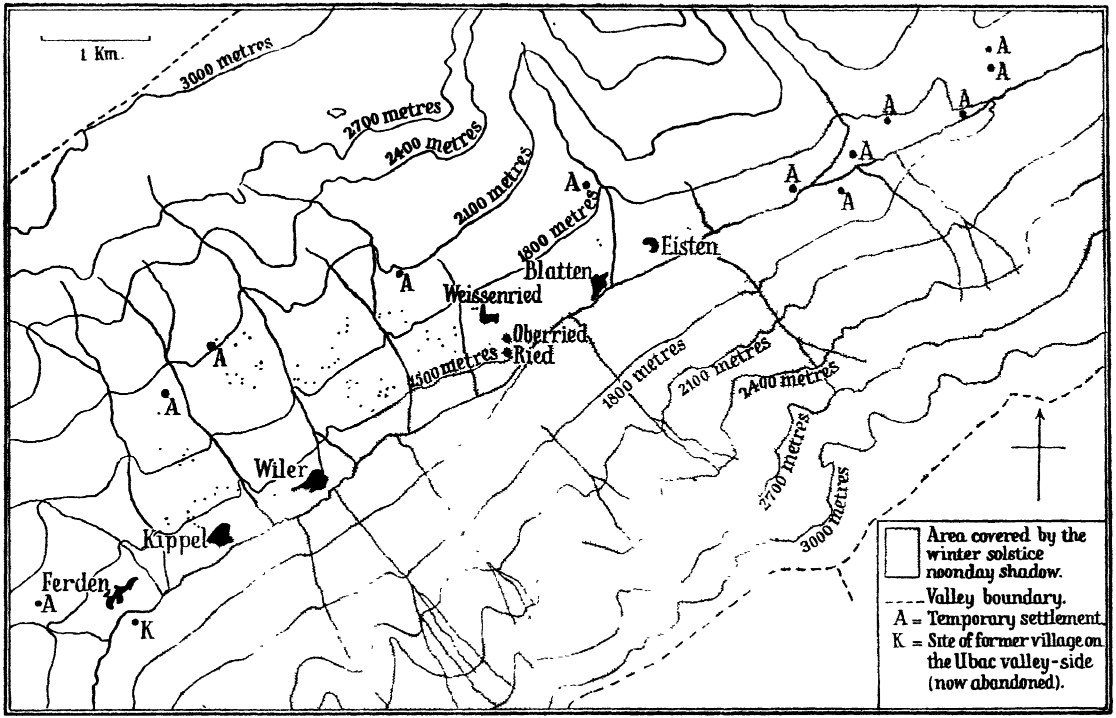

Fig. 34. Settlements in the Lötschenthal in relation to the Winter Solstice Shadow Area

reading. The maximum available intensity (100 per cent.) is realized when a ray of sunlight meets the surface at right angles in both planes—horizontal and vertical. The percentage intensity at any point can be calculated as equal to $\cos a \cos b \pm \sin a \sin b \cos c$ where a = the angle of slope (which can be calculated from the contour H.E.), b = the complement of the sun's altitude, c = the angle between the azimuth of the sun and the azimuth of the direction of the slope—*i.e.*, at right angles to the valley direction. (The positive sign is used when the aspect is toward the sun, and the negative when the aspect is away from the sun.)

According to this method of calculation, the following percentages of the maximum available sun-intensity are received at noon on slopes just above Weissenried and on the opposite valley-side at corresponding altitudes:

—	Percentage Noon Intensity		
	Equinox	Summer Solstice	Winter Solstice
Weissenried (1770–1680 m.)	85	100	57
Opposite valley-side (1770–1680 m.)	41	72	0

These figures show how, through map-reading alone, a geographical fundamental in the study of Alpine regions can be measured with some degree of precision. (For other methods of map analysis to show settlements, land utilization, etc., in relation to time periods and intensity of insolation, see the *Geographical Review*, 1935, *op. cit.*, and *Insolation and Relief*, by A. Garnett (The Institute of British Geographers, published by George Philip, London, 1937).)

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